Biofouling Monitoring for Aquatic Invasive Species (AIS) in DFO Maritimes Region, Nova Scotia: May – December 2011.

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ABSTRACT

Sephton, D., Stiles, L., and Vercaemer, B. 2015. Biofouling monitoring for aquatic invasive species (AIS) in Nova Scotia; May - December 2011. Can. Tech. Rep. Fish. Aquat. Sci. 3082. vii + 70 p.

The establishment of four species of invasive tunicates: *Ciona intestinalis*, *Botryllus schlosseri*, *Botrylloides violaceus* and *Styela clava* has had detrimental impacts on the shellfish culture industry in Atlantic Canada. Three additional species of concern: *Didemnum vexillum*, *Diplosoma listerianum* and *Ascidiella aspersa* have not been reported in the region up to 2011. An annual surveillance and monitoring program for tunicates and other invasive biofoulers, including *Capreila mutica* and *Membranipora membranacea,* was initiated in 2006 in DFO Maritimes Region. This report summarizes the 2011 monitoring conducted at geo-referenced coastal monitoring stations in the Nova Scotia portion of DFO Maritimes Region. Thirty-one stations were monitored during three deployment periods; first (May - August), second (August - October) and full (May – October). Water temperature, salinity and oxygen content were measured at each deployment and collection, and various surfaces were examined for tunicate fouling and the presence of other invasive species. Six additional reports of tunicate presence or absence were received in 2011.

Styela clava, D. vexillum, D. listerianum and *A. aspersa* were not detected in 2011. *Ciona intestinalis* was found at 21 of 31 monitoring stations, and reported from five locations. *Botryllus schlosseri* was the most wide-spread species; found at 26 of 31 monitoring stations, and reported at two locations. *Botrylloides violaceus* was found at 16 of 31 monitoring stations, and reported at one location. Four stations were free of tunicates. *Ciona intestinalis*, *B. schlosseri* and *B. violaceus* were all present at 16 stations. Tunicates were found in waters with 4.8 – 23.4°C temperature, 14.9 – 32.6 salinity, and 2.45 – 10.41 mg L^{-1} dissolved oxygen.

Ciona intestinalis dominated (moderate to heavy) the biofouling community on collector plates at many stations in southwestern NS, along the south shore, in Chedabucto Bay and along the coast of Cape Breton. *Botryllus schlosseri* was the dominant tunicate in the Bras d'Or Lake, (moderate to very heavy), but it was found (low to moderate) throughout the province. *Botrylloides violaceus* was recorded as a low fouler at many locations. Only part of the north shore of Nova Scotia (Northumberland Strait) was tunicate free in 2011.

Caprella mutica and *M. membranacea* were present throughout Nova Scotia in 2011; at 12 and 24 of 31 monitoring stations, respectively.

RÉSUMÉ

Sephton, D., Stiles, L., and Vercaemer, B. 2015. Surveillance de biosalissures pour les espèces aquatiques envahissantes (EAE) dans la région de Maritimes de DFO, Nouvelle-Écosse :mai-décembre 2011. Can. Tech. Rep. Fish. Aquat. Sci. 3082 : vii + 70 p.

Le développement de quatre espèces de tuniciers envahissants: *Ciona intestinalis*, *Botryllus schlosseri*, *Botrylloides violaceus* et *Styela clava* a eu des répercussions néfastes sur l'industrie de la conchyliculture au Canada atlantique. Un programme de surveillance et de suivi annuel des tuniciers et d'autres bio salissures envahissantes, y compris *Caprella mutica* et *Membranipora membranacea*, a débuté en 2006 aux stations de surveillance côtières géo-référencées dans la partie Nouvelle-Écosse de la Région des Maritimes du MPO. Ce rapport résume les résultats de la surveillance de 31 stations en 2011 au cours de trois périodes de déploiement; première (mai - août), deuxième (août - octobre) et complète (mai - octobre). La température de l'eau, la salinité et la teneur en oxygène ont été mesurées à chaque déploiement et collecte, et différentes surfaces ont été examinées pour évaluer l'encrassement des tuniciers et la présence d'autres espèces envahissantes. Six rapports de présence ou d'absence de tuniciers ont été reçus en 2011.

Styela clava, D. vexillum, D. listerianum et *A. aspersa* n'ont pas été détectés en 2011. *Ciona intestinalis* a été retrouvé à 21 des 31 stations de surveillance, et signalé dans 5 endroits. *Botryllus schlosseri* est l'espèce la plus répandue, présente à 26 des 31 stations de surveillance, et rapportée à 2 endroits. *Botrylloides violaceus* a été trouvé sur 16 des 31 stations de surveillance, et signalé dans 1 endroit. Quatre stations étaient libres de tuniciers, et ils n'étaient pas présents à 3 des endroits signalés, tandis que les 3 espèces de tuniciers étaient toutes présentes dans 16 stations. Les 3 espèces de tuniciers présentes en Nouvelle-Écosse ont été trouvés dans des eaux de 4,8 – 23,4°C de temperature, 14,9 à 32,6 de salinité, et de 2,45 à 10,41 mg L-1 d'oxygène dissous.

Ciona intestinalis domine (de façon modérée à forte) la communauté des biosalissures sur les plaques dans de nombreuses stations du sud-ouest Nouvelle-Écosse, le long de la rive sud, dans la baie Chedabucto et dans la région côtière du Cap-Breton. *Botryllus schlosseri* était l'ascidie dominante dans le lac Bras d'Or, (modérée à très forte), mais elle a été observé (faible à modérée) dans toute la province. *Botrylloides violaceus* a été observé en tant que faible biosalissure en de nombreux endroits. Seule une partie de la rive nord de la Nouvelle-Écosse a été libre de tuniciers en 2011.

Caprella mutica et *M. membranacea* étaient présents tout le long de la Nouvelle-Écosse en 2011; à 12 et 24 des 31 stations de surveillance, respectivement.

1.0 INTRODUCTION

Non-indigenous species (NIS) can pose great risk to native species, native biodiversity, and can negatively impact native ecosystems and their function (Sala et al. 2000). Among NIS of global concern, ascidian tunicates, commonly known as sea-squirts, have affected marine ecosystems through their negative impacts on native species (Lambert 2001; Lutz-Collins et al. 2009) and communities (Blum et al. 2007; Dijkstra et al. 2007; Lambert and Lambert 1998, 2003; Lengyel et al. 2009). Tunicates pose a serious threat to shellfish aquaculture operations as they overgrow bivalves and gear (Carver et al. 2003; Bullard et. al. 2007), resulting in increased operation and production costs (MacNair et al. 2006). Some tunicate infestations have resulted in decreased productivity and growth of blue mussels, *Mytilus edulis* (Linnaeus, 1758) (Daigle and Herbinger 2009), and significant losses to the mussel culture industry in Prince Edward Island (PEI) and Nova Scotia (NS) since the mid 1990's (Boothroyd et al. 2002; Clarke and Therriault 2007; Howes et al. 2007; Ramsay et al. 2008). A NIS is deemed invasive when it poses ecological and/or economic threat.

Three species of invasive, fouling tunicates are now well established on the Atlantic coastal of Nova Scotia (Carver et al. 2006a,b; Sephton et al. 2011, 2014); the solitary vase tunicate, *Ciona intestinalis* (Linneaus, 1776), and two colonial species; the golden star tunicate *Botrylius schlosseri* (Pallas 1766), and the violet tunicate, *Botrylloides violaceus* (Oka, 1927). Several potential invaders to the region have been identified by Locke (2009): the solitary clubbed tunicate *Styela clava* (Herdmann 1881), the solitary European sea squirt *Ascidiella aspersa* (Muller, 1776), the colonial compound sea squirt *Diplosoma listerianum* (Milne-Edwards, 1841), and the colonial pancake batter tunicate, *Didemnum vexillum* (Kott, 2002). Two non-tunicate biofouling species; the Japanese skeleton shrimp, *Caprella mutica* (Schurin, 1935) and the lacy-crust bryozoan, *Membranipora membranacea* (Linnaeus, 1767) are also present and threaten marine ecosystems and native species in the region.

In response to the growing threat posed by aquatic invasive species (AIS) to native coastal communities, fisheries and shellfish aquaculture in Atlantic Canadian waters, Fisheries and Oceans Canada (DFO) developed and initiated an AIS Biofouling Monitoring Program in 2006 (Sephton et al. 2011, 2014). Here we report on the monitoring for invasive biofouling species conducted in the Nova Scotia portion of DFO Maritimes Region, NS between May and December 2011.

2.0 MATERIALS AND METHODS

2.1. STATION SELECTION

Coastal and inland (Bras d'Or Lake) general monitoring stations were selected based on the presence of potential or existing "risk factors" for the introduction and spread of AIS. These included; (1) presence of shellfish or mussel processing facilities, (2) mussel or shellfish aquaculture sites, (3) important commercial port with international traffic, (4) marina or yacht club with US traffic, (5) commercial fishing harbours, and (6) harbours with herring or US lobster processing facilities. Sites with air-exposure at low tide (for example, in the upper Bay of Fundy Coast) were not included. Thirty-one geo-referenced stations were monitored in 2011 (Table 1): 22 of these were monitored in 2010, seven stations (13, 25, 39, 44, 45, 58 and 75) were monitored at least once between 2006 and 2009 but not in 2010 and two (Little River and Sambro) were new monitoring stations added at the request of DFO clients.

2.2. MONITORING COLLECTORS

The monitoring collector shown below (Figure 1) and described by Sephton et al. (2011, 2014) was used in 2011.

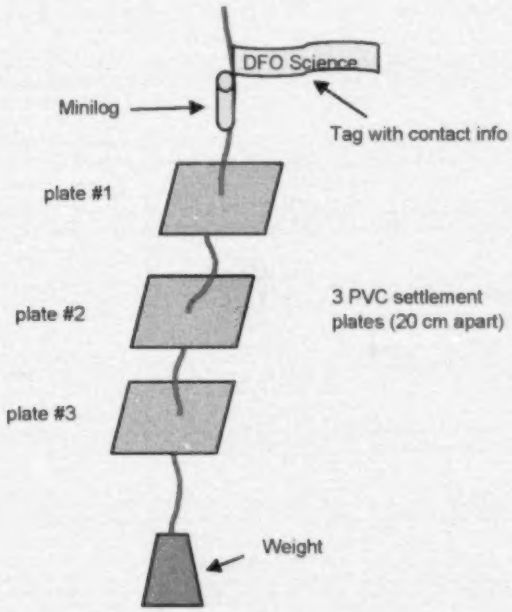


Figure 1: AIS plate collector used in biofouling monitoring in 2011.

Table 1: Aquatic Invasive Monitoring Stations, 2011. SW = southwestern shore (Digby to Clark's Harbour), S = shore (Lockeport to Chester), HRM = Halifax Regional Municipality, E = eastern shore (Ship Harbour to Whitehead), Ched. Bay = Chedabuto Bay (Cape Canso to Ile Madame), and CB = Cape Breton.

Stn No.	Region	Location	Latitude, °N	Longitude, °W	Station Description and Deployment Structure
1	SW	Digby	44.63015	-65.75233	Royal Western Nova Scotia Yacht Club marina, large, mixed-use port, floating dock
2	SW	Meteghan	44.19365	-66.16688	Medium fishing and processing port, public wharf, floating dock
4	SW	Yarmouth Bar	43.81648	-66.14785	Medium fishing and processing port, public wharf, floating dock
7	SW	Camp Cove	43.72360	-65.84057	Medium fishing and processing port, public wharf, floating dock
108	SW	Eel Lake	43.82670	-65.90770	Shellfish aquaculture site, lines, buoys oyster cages
8	SW	Clark's Harbour	43.44470	-65.63510	Medium fishing and processing port, public wharf, floating dock
12	S	Shelburne	43.75750	-65.32200	Shelburne Yacht Club marina, medium, mixed-use port, floating dock
13	S	Lockeport	43.69950	-65.10740	Medium, mixed- use port, public wharf
82	S	Port Mouton	43.91940	-64.84340	Small fishing and processing port, public wharf,
18	S	Lunenburg	44.37525	-64.33069	Large, mixed-use port and shellfish aquaculture area, public wharf, floating dock
19	S	Indian Point	44.45598	-64.30683	Indian Point Marine Farms (IPMF), shellfish aquaculture site, mussel lines
21	S	Chester	44.53780	-64.23840	Medium, mixed-use port, shellfish aquaculture area, public wharf, floating dock

Table 1: Aquatic Invasive Species Monitoring Stations, 2011, continued.

Stn No.	Region	Location	Latitude, °N	Longitude, °W	Station Description and Deployment Structure
83	HRM	Sambro	44.47861	-63.59953	Medium fishing harbour, public wharf floating dock
24	HRM	Halifax; BIO Jetty	44.68187	-63.61187	Large, international, mixed-use port, government wharf at Bedford Institute of Oceanography
25	E	Ship Harbour	44.81240	-62.87200	Shellfish aquaculture site, mussel lines
39	E	Cape Canso	45.33450	-60.98610	Small fishing harbour, public wharf, floating dock
41	Ched. Bay	Venus Cove	45.61530	-61.39010	Venus Cove Marine Park marina, small fishing and recreational port near large, international port, public wharf, floating dock
44	Ched. Bay	Petit-de-Grat	45.50710	-60.96050	Medium, mixed-use port, public wharf, floating dock
45	Ched. Bay	D'Escousse	45.58870	-60.96180	Lennox Passage Yacht Club, marina, floating dock
47	Bras d'Or Lake	St. Peter's	45.66115	-60.87440	St. Peter's Lion's Club marina, entrance to Bras d'Or Lake, floating docks
51	Bras d'Or Lake	Whycocomagh	45.98640	-61.11260	Small recreational harbour, shellfish aquaculture area, public wharf, floating dock
52	Bras d'Or Lake	Orangedale	45.90070	-61.08955	Small recreational harbour, shellfish aquaculture area, public wharf, floating dock
86	Bras d'Or Lake	East Bay	46.01360	-60.38920	Aquaculture Education site, buoys
54	Bras d'Or Lake	Eskasoni	45.95570	-60.58530	Unama'ki Institute of Natural Resources, small harbour, private wharf

Table 1; Aquatic Invasive Species Monitoring Stations, 2011, continued.

Stn No.	Region	Location	Latitude, °N	Longitude, °W	Station Description and Deployment Structure
55	Bras d'Or Lake	Baddeck	46.09990	-60.74752	Medium recreational harbour, public wharf, floating dock
62	CB	Sydney	46.13993	-60.16775	Royal CB Yacht Club marina, near US and international cruise ship port, floating dock
63	CB	North Sydney	46.20680	-60.24900	Large, mixed-use port, near Newfoundland Ferry terminal, public wharf, floating dock
69	CB	Dingwall	46.90320	-60.46040	Small fishing port, shellfish aquaculture
74	CB	Little River	46.44712	-60.45936	Public wharf, floating dock
75	CB	St. Ann's Bay	46.25140	-60.58710	Mussel lease
58	CB	Louisbourg	45.91798	-59.98935	Public wharf, floating dock

2.3. MONITORING PROTOCOL

Twenty-six stations of 31 stations were monitored by staff from DFO Science Branch, Maritimes Region, Coastal Ecosystem Research Division. Additional stations were monitored by: Clean Annapolis River Project (CARP: Digby, Station 1), Eskasoni Fish and Wildlife Commission (EFWC: Whycocomagh, Station 51; Orangedale, Station 52 and Eskasoni, Station 54), and DFO Eastern Nova Scotia Area Office, Conservation and Protection Branch (East Bay, Station 86). The Nova Scotia Department of Fisheries and Aquaculture (NSDFA) provided information from four shellfish aquaculture sites, and two reports (Halifax; Armdale Yacht Club (AYC) and Little Harbour) were noted by DFO Science staff (Table 2).

Table 2: Location of AIS reports not from monitoring plates in 2011.

Station No.	Region	Location	Latitude °N	Longitude °W	Station Description
401	HRM	Halifax; AYC	44.63588	-63.6131	Armdale Yacht Club, private marina
104	Eastern shore	Country Harbour	45.23220	-61.75900	Mussel lease
36	Eastern shore	Whitehead	45.23297	-61.15875	Mussel lease
46	Cape Breton	Little Harbour	45.58333	-60.74067	Fishing harbour
80	Chedabucto Bay	Robin's Cove; IMBC	45.5062	-61.09990	Ile Madame Boat Club, private
94	Cape Breton	Aspy Bay, North Harbour	46.90702	-60.47023	Mussel lease

Four collectors (Figure 1) were deployed (hung) with the top plate approximately 1 m below the water surface at each site in late May to mid-June. Collectors deployed at fishing harbours and marinas were hung from floating docks while collectors on shellfish aquaculture leases were hung at the depth of the mussel socks: 5m at Indian Point (Station 19) and on oyster cages at Eel Lake (Station 108). Collectors were deployed in such a way that multiple areas representative of differing habitats (sheltered or higher current) of the station were sampled. Seasonal differences in colonization were determined by removing two collectors in mid-August (first deployment period) and deploying two more collectors in mid-August for retrieval in late October (second deployment). The two collectors that remained in the water from late May to mid-June

were also retrieved in late October to mid-November and were used to assess full season colonization (full deployment period) on collector plates. At sites where biofouling had been low in previous years, or where it was not logistically feasible to visit the site in summer, the four collectors deployed in late May to mid-June were retrieved in late October to mid-November (full deployment period only). Dates and details of 2011 collector deployment for all stations are shown in Appendix 1.

A Garmin eTrex Unit (Garmin International, Inc., Olathe, Kansas, USA) was used to determine or verify the geo-referenced position of each monitoring station and photographs of new stations were taken in May. Temperature (°C), salinity, conductivity (mS cm^{-1}) and oxygen content (% saturation and mg L^{-1}) were measured at collector depth using a YSI 6600 Sonde (YSI Incorporated, Yellow Springs, Ohio, USA) at each deployment and retrieval at most stations. A Hydrolab-Quanta (Hach Hydromet, Loveland, Colorado, USA) instrument was used at Station 1 (Digby), while a YSI 85 was used at Eskasoni, Orangedale and Whycocomagh. The YSI 6600 Sonde also measured chlorophyll A (μg L^{-1}). VEMCO (AMIRIX Systems, Inc., Bedford, Nova Scotia, Canada) minilog-T8k temperature recorders were attached to one of the full season monitoring collectors (Figure 1) at seven stations (see Appendix 1). A visual check of surfaces and structures adjacent to collectors was made at each station at each visit using an underwater viewer to document the presence of tunicates and other NIS (Table 3).

Table 3: List of non-indigenous aquatic species (NIS) subject to detection and monitoring in 2011. * is a species usually not attached to collector plates.

Group	Scientific Name	Common Name (s)
Tunicates	*Ciona intestinalis*	Vase tunicate
	Botryllus schlosseri	Golden star tunicate
	Botrylloides violaceus	Violet tunicate
	Styela clava	Clubbed tunicate
	Didemnum vexillum	Pancake batter tunicate
	Diplosoma listerianum	Compound sea squirt
	Ascidiella aspersa	European sea squirt
Bryozoans	*Membranipora membranacea*	Coffin box, lacy crust bryozoan
Crustaceans	*Caprella mutica*	Japanese skeleton shrimp
	*Carcinus maenas**	European green crab
	*Eriocheir sinensis**	Chinese mitten crab
	*Hemigrapsus sanguineus**	Asian shore crab
Algae	*Codium fragile spp. fragile**	Oyster thief, Codium, green fleece

Collectors were removed at the end of each monitoring period and collector ropes, tags and weights were examined in the field for the presence of tunicates, other NIS and biofouling native species. These data were recorded in the field, and then entered into a Microsoft ACCESS database for analysis. Deployment dates, periods and AIS coverage on individual monitoring plates are given in Appendix 1.

Individual monitoring plates were cut free of each collector and placed bottom-side up in sequence (top plate = left (1), middle plate = centre (2) and bottom plate = right (3)) on a white, labelled background. The plates were photographed using a frame-mounted Panasonic Lumex TS3 (Panasonic Inc., Mississauga, Ontario) digital camera. Ideally, photographs were taken in the field, but under adverse weather conditions or when partners shipped collectors to the Bedford Institute of Oceanography (BIO), photographs were taken indoors within 24 h of collection.

2.4 DETERMINATION OF PRESENCE AND PERCENT COVERAGE OF TUNICATES

Presence of tunicate species was determined as a positive observation on either a DFO monitoring collector (plates, rope, tag or weight) or on a submerged surface inspected at the monitoring station, or as a report provided by a monitoring partner.

Percent coverage of each tunicate species was determined by visual examination of the bottom (under) surfaces of each plate. Categories for the percent coverage were: 0 (absent); 1: < 25% coverage (low); 2: 25–50% coverage (moderate); 3: 51–75% coverage (heavy), and 4: 76-100% coverage (very heavy). A value of "1" was assigned to plate 1 of a collector where one to a few individual tunicates were present on collector surfaces other than plates (see above).

The average percent coverage category for each species of tunicate at each station was determined separately for each deployment period (first, second and full). The category values of each plate were converted to their median numerical value, as follows: 0 = 0 %, 1 = 12.5 %, 2 = 37.5 %, 3 = 62.5 % and 4 = 87.5%. The average coverage value for a deployment period was calculated as the sum of the median values divided by the total number of plates recovered (i.e. six plates for two collectors, or three plates if only one collector was recovered). The year average percent coverage was determined as the sum of all median values divided by the total number of plates recovered in all deployment periods (i.e. maximum of eighteen plates for six monitoring collectors). Average median values for each deployment period and for the year average were converted to the appropriate category value to construct coverage histograms for each station, and distribution maps for each species.

3.0 RESULTS

3.1 GENERAL OCCURRENCE

General results for the presence of tunicate species monitored in 2011 are given in Table 4, and the locations where *C. intestinalis*, *B. schlosseri*, and *B. violaceus* were present are shown in Figure 2.

Table 4: Prevalence of AIS (monitoring records or non-plate reports) in Nova Scotia, May – December 2011.

Species	Monitoring Sites N=31	Non-Plate Reports N=6	Total Records N=37
Ciona intestinalis	21	5	26
Botryllus schlosseri	26	2	28
Botrylloides violaceus	16	1	17
Styela clava	0	0	0
Didemnum vexillum	0	0	0
Diplosoma listerianum	0	0	0
Ascidiella aspersa	0	0	0
No Tunicates	4	1	5
Caprella mutica	12	0	12
Membranipora membranacea	24	0	24

Botryllus schlosseri was the most frequently recorded tunicate; present at 26 monitoring stations and reported at two additional locations (76% of total records), followed by *C. intestinalis*, found at 21 monitoring stations, and reported from five additional sites (70% of records). *Botrylloides violaceus* was the least frequently recorded tunicate; present at 16 monitoring stations and reported from one additional location (46% of records). *Styela clava*, *D. vexillum*, *D. listerianum* and *A. aspersa* were not detected in 2011. *Ciona intestinalis* was reported for the first time at Louisbourg, while *C. intestinalis, B. schlosseri and B. violaceus* were formally reported for the first time at Sambro, and *B. schlosseri* was reported at Little River, both new monitoring stations in 2011. Tunicates were not present at four stations: Ship Harbour, Orangedale, St. Ann's and Eel Lake and were reported absent at one location: Aspy Bay, North Harbour (Figure 2).

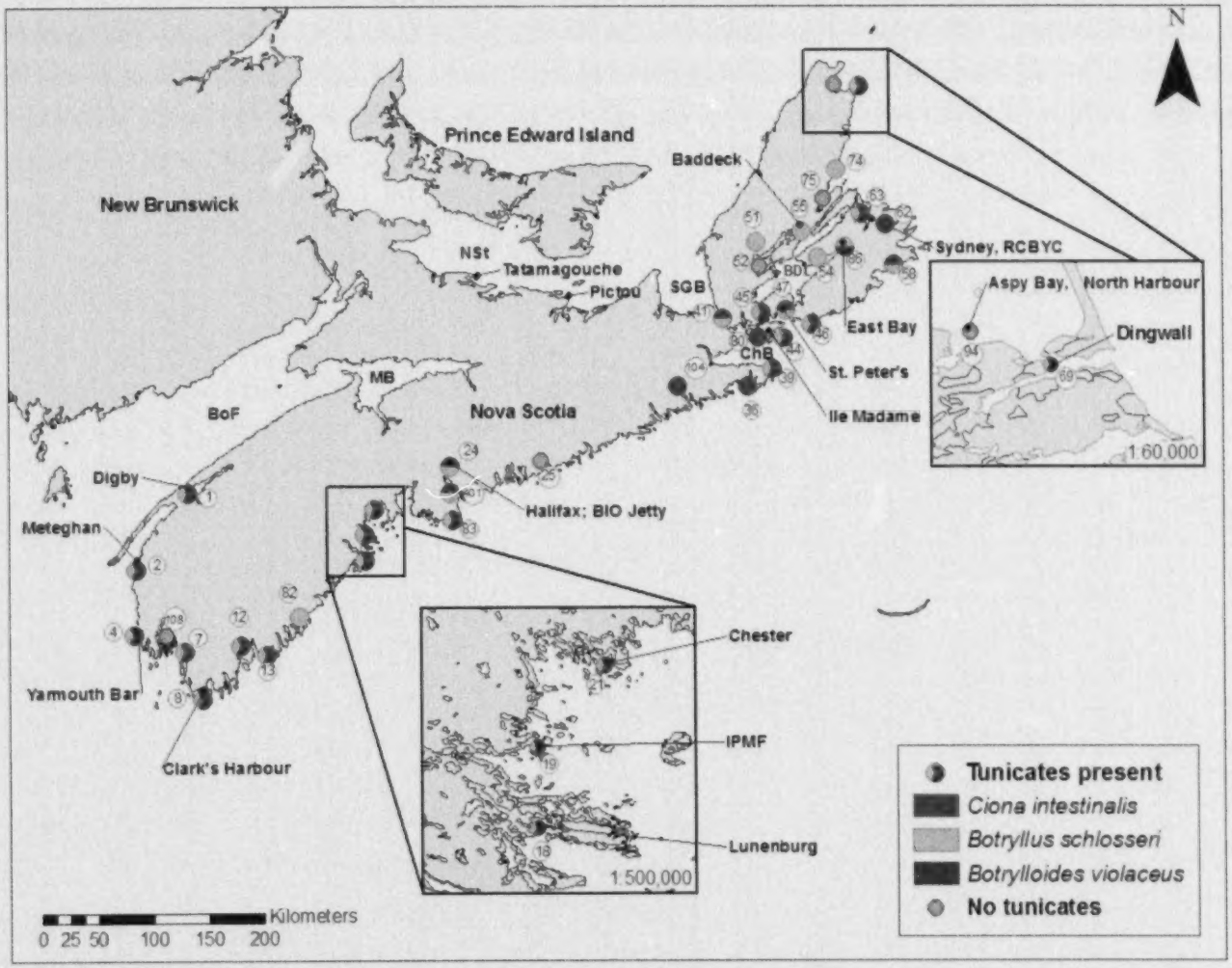


Figure 2: Presence of *Ciona intestinalis, Botryllus schlosseri* and *Botrylloides violaceus* in Nova Scotia in 2011. BoF = Bay of Fundy, ChB = Chedabucto Bay, MB = Minas Basin, NSt = Northumberland Strait, SGB = St. Georges Bay and BDL = Bras d'Or Lake.

DFO Gulf Region monitored nine stations on the north shore of mainland NS and the Gulf of St. Lawrence side of Cape Breton in 2011 and reported the presence of *B. schlosseri* at three monitoring stations: Cribbon's Point and Ballantyne's Cove in St. George's Bay (SGB, Figure 2), and Cheticamp, while *B. violaceus* was also noted at Cheticamp (R. Bernier, pers. comm). Tunicates were not reported at Tatamagouche or Pictou on the north shore.

Overall, *Ciona intestinalis* was present in many regions of Nova Scotia (Figure 2), with the exception of the inner Bras d'Or Lake, and the north shore (R. Bernier, pers. comm.). *Botryllus schlosseri* was widespread throughout the province and was the only tunicate species recorded in Bras d'Or Lake (Figure 2). *Botrylloides violaceus* was also found in many regions, except in the Bras d'Or Lake or on the north shore (Figure 2).

3.2 ENVIRONMENTAL RANGES

The ranges of temperature, salinity and dissolved oxygen concentration at sites where tunicates were present during the study period are shown in Table 5. Raw YSI values from each station visit are given in Appendix 2, and Minilog temperature plots are shown in Appendix 3.

Table 5: Ranges of values for temperature, salinity, and dissolved oxygen at stations where invasive tunicate species were present, May – December 2011.

Species	YSI Temperature Range (°C)	Minilog Temperature Range (°C)	YSI Salinity Range	YSI Oxygen Range (mg L^{-1})
Ciona intestinalis	4.8 – 22.0	2.0 – 20.0	18.10 – 33.20	5.20 – 10.41
Botryllus schlosseri	7.5 – 23.4	2.0 - 22.4	14.90 – 32.60	2.45 – 10.41
Botrylloides violaceus	5.2 – 22.5	2.0 – 20.0	23.90 – 32.60	5.20 – 10.41
No Tunicates	7.0 – 16.4	5.0 - 24.7	12.58 – 20.26	8.71 – 11.37

The YSI ranges were determined from discrete 1m depth measurements taken during each of the three station visits, and do not reflect the true range of temperature, or other environmental measures at each station. Minilog recording thermistors tracked hourly temperatures throughout the study period at seven stations, and gave temperature maxima and minima, as well as patterns of daily and seasonal variation at these locations (Appendix 3). At Digby, Eel Lake, Lockeport and Indian Point, on the southwest and south shores, a general pattern of warming from spring to maximum temperatures in late July (Lockeport: 19.5°C, July 31) or mid to late August (IPMF:

20°C, Aug. 17) was evident. Eel Lake, an inland brackish lake, was the warmest station in this region, where temperature reached 24.7°C on July 24, while Digby was the coolest station, where temperatures generally remained between 10°C and 15°C for most for the deployment period. At Ship Harbour, on the eastern shore, temperatures ranged from 10°C to a high of 18°C in mid-August, followed by cooling to about 8°C in early December. At Eskasoni, in the Bras d'Or Lake, temperature rose from a low of 12°C in early June to a high of 22.4°C on Sept. 3, declining to about 10°C in early November. At Aspy Bay, North Harbour, water temperature peaked at 20.5°C in early September, and declined to a low of 5°C in late November. Following summer temperature maxima, a general pattern of declining temperature, punctuated by short-term cycles of heating and cooling in September and/or October was at these stations evident (Appendix 3).

Ciona intestinalis was present at sites with late-summer temperatures as high 20.0°C, and with early spring lows of 2.0°C (IPMF, Table 5). Of the two colonial species observed, *B. violaceus* was present in waters as warm as 20.0°C, while *B. schlosseri* was present at a warmer site with waters up to 22.4°C. Tunicates were not present at Eel Lake, Ship Harbour, or Aspy Bay, North Harbour, where the combined temperature ranges recorded were from a low of 5°C to a high of 24.7°C. *Botryllus schlosseri* tolerated a wider salinity range than the other species and was present in brackish waters as low as 14.9 (Eskasoni), but tunicates were not found in Orangedale, with a salinity minimum of 12.58. Tunicates tolerated a wide range of oxygen concentrations, from 2.45 to 10.41 mg L^{-1} (Appendix 2).

Chlorophyll values recorded during station visits (Appendix 2) were highly variable. Chlorophyll, an indicator of food availability for filter-feeding tunicates and bivalves, ranged from 0.06 – 3.8 μg L^{-1} during the full monitoring period, and there was no consistent seasonal pattern at any station.

3.3 TUNICATE COVERAGES (DEGREE OF INFESTATION)

As was noted in 2010 (Sephton et al. 2014), there was variation in tunicate coverage (i.e. "patchiness"): (1) among individual plates on a collector, (2) between duplicate collectors at a site during a deployment period, and (3) among deployment periods (Appendix 1). The year average coverage, determined from data recorded on all monitoring collectors gave a comparable approximation of the level of infestation on fouled structures at each station.

The year (annual) average percentage coverages (over all plates and collectors) recorded at all stations monitored in 2011 are shown for *C. intestinalis* (Figure 3), *B. schlosseri* (Figure 4) and *B. violaceus* (Figure 5).

3.3.1 *Ciona intestinalis*

Average annual coverage of *C. intestinalis* was very heavy (76-100%) at Shelburne and at Camp Cove, and heavy (51-75%) at Petit-de-Grat (Figure 3). The two full season collectors recovered from Sambro were completely fouled by vase tunicates (100 %), however, since no seasonal information was available, this result is not strictly comparable with results from the other heavily infested stations where six collectors were deployed. Moderate (26-50%) coverages were noted at Meteghan, in Lunenburg and Indian Point (Leases 1 and 3) and at Louisbourg, while low (<25%) coverages were noted at many stations throughout the province. Low to moderate coverages were noted on the eastern shore (A. Bagnall, pers. comm).

3.3.2 *Botryllus schlosseri*

Average annual coverage of *B. schlosseri* was moderate (26-50%) at Chester and St. Peter's (Figure 4). Low (<25%) coverages of this species were noted throughout the province, and it was present at every station monitored on the southwestern and south shores, and the only species present in Bras d'Or Lake. It was reported as present at the Armdale Yacht Club (Halifax) and at Little Harbour (Cape Breton).

3.3.3 Botrylloides violaceaus

Average annual coverage of *B. violaceus* was moderate (26-50%) at Lockeport and at North Sydney (Figure 5). Low (<25%) average coverages were noted at stations on the southwestern and south shores, at Cape Canso, on Ile Madame, and at Dingwall. It was also reported as present at Little Harbour (Cape Breton).

3.3.4 No Tunicates Present

Tunicates were not detected at four stations: Ship Harbour, Orangedale, St. Ann's and Eel Lake in 2011(Figure 2), and they were reported absent from one location: Aspy Bay, North Harbour.

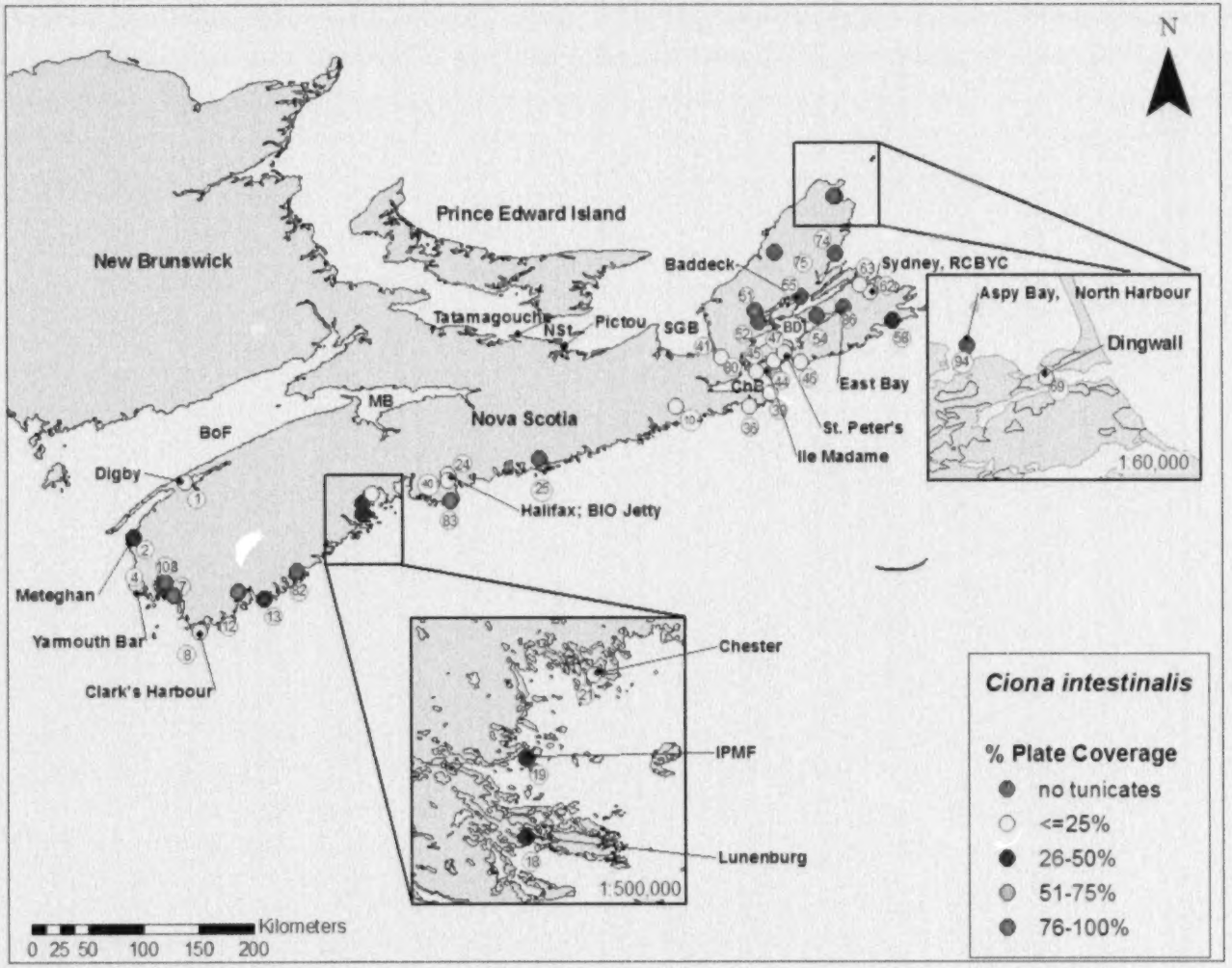


Figure 3. Average annual percentage coverage of *Ciona intestinalis* on monitoring collectors in 2011. Non-monitoring plate reports (see Table 2) are given as absent or present (< 25%). BoF = Bay of Fundy, ChB = Chedabucto Bay, MB = Minas Basin, NSt = Northumberland Strait, SGB = St. Georges Bay and BDL = Bras d'Or Lake.

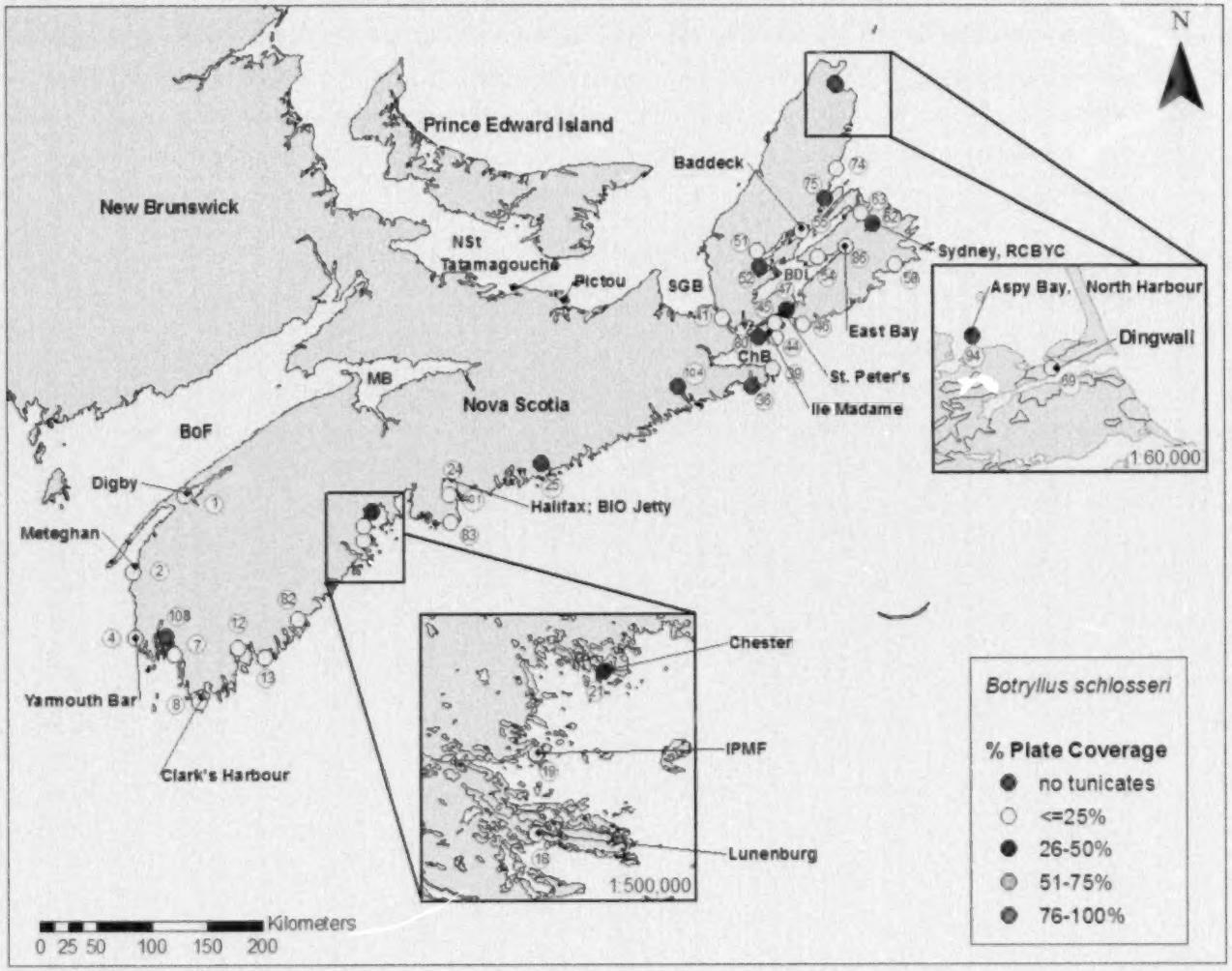


Figure 4. Average annual percentage coverage of *Botryllus schlosseri* on monitoring collectors in 2011. Non-monitoring plate reports (see Table 2) are given as absent or present (< 25%). BoF = Bay of Fundy, ChB = Chedabucto Bay, MB = Minas Basin, NSt = Northumberland Strait, SGB = St. Georges Bay and BDL = Bras d'Or Lake.

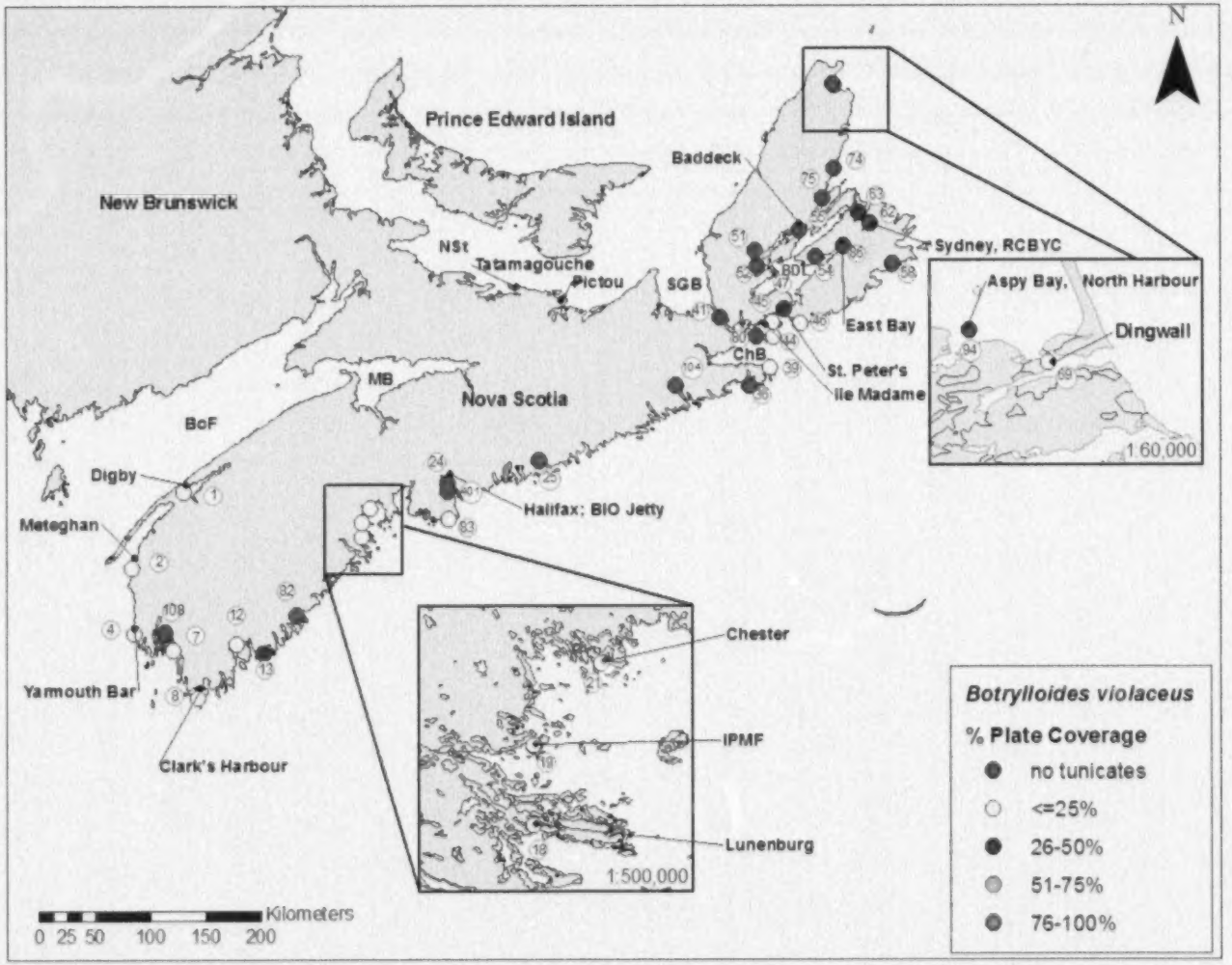


Figure 5. Average annual percentage coverage of *Botryllus violaceus* on monitoring collectors in 2011. Non-monitoring plate reports (see Table 2) are given as absent or present (< 25%). BoF = Bay of Fundy, ChB = Chedabucto Bay, MB = Minas Basin, NSt = Northumberland Strait, SGB = St. Georges Bay and BDL = Bras d'Or Lake.

3.4 OTHER BIOFOULING ORGANISMS

3.4.1 *Membranipora membranacea*

The lacy crust bryozoan, *M. membrancea*, was present on monitoring collectors deployed at 24 of 31 monitoring sites throughout the province (Figure 6). Sites included marinas, small to large fishing harbours, and mussel farms, and there was no clear regional pattern of occurrence.

3.4.2 *Caprella mutica*

The Japanese skeleton shrimp, *C. mutica,* was found on monitoring collectors deployed at 12 of 31 monitoring stations (Figure 7). It was found in all regions of the province, and at marinas, harbours and on mussel farms.

3.5 SEASONAL VARIATION IN TUNICATE PRESENCE (Appendix 1)

3.5.1 Southwestern shore (Digby to Clark's Harbour)

Ciona intestinalis was present on first, second and full deployment collectors at Camp Cove (Figure 8E) and Clark's Harbour (Figure 8F). Its absence on first deployment collectors at Digby (Figure 8A) may be due to low water temperatures (Appendix 3), while its absence during the second deployment period at Meteghan (Figure 8B), and during the second and full deployment periods at Yarmouth Bar (Figure 8C) may reflect patchy or low settlement. Settlement by *C. intestinalis* was heaviest in this region at Camp Cove (Figure 8E) during all deployment periods. Heavier coverages were noted on full season collectors at Meteghan (4: 76-100%) and at Clark's Harbour (2: 25-50%), which may reflect growth of early settlers, or continuous recruitment. Heaviest year average coverages were noted at Camp Cove (4: 76-100%), with moderate (2: 25-50%) coverages at Meteghan, and low (1: <25%) coverages at Digby, Clark's Harbour and Yarmouth Bar.

Botryllus schlosseri was present on all collectors at Camp Cove (Figure 8E) and Clark's Harbour (Figure 8F). It was absent during the first deployment at Digby (Figure 8A), during the second deployment at Yarmouth Bar (Figure 8C), and on full season collectors at Meteghan (Figure 8B), when plates were totally covered by vase tunicates. Coverages were low (1: <25%) at most stations, but moderate (2: 25-50%) coverages were noted on second and full deployment collectors at Clark's Harbour, which may reflect higher settlement and growth as the water warmed.

Coverage of *B. violaceus* was low during all deployment periods. They were absent during the first deployment at Digby (Figure 8A) and Clark's Harbour (Figure 8F),

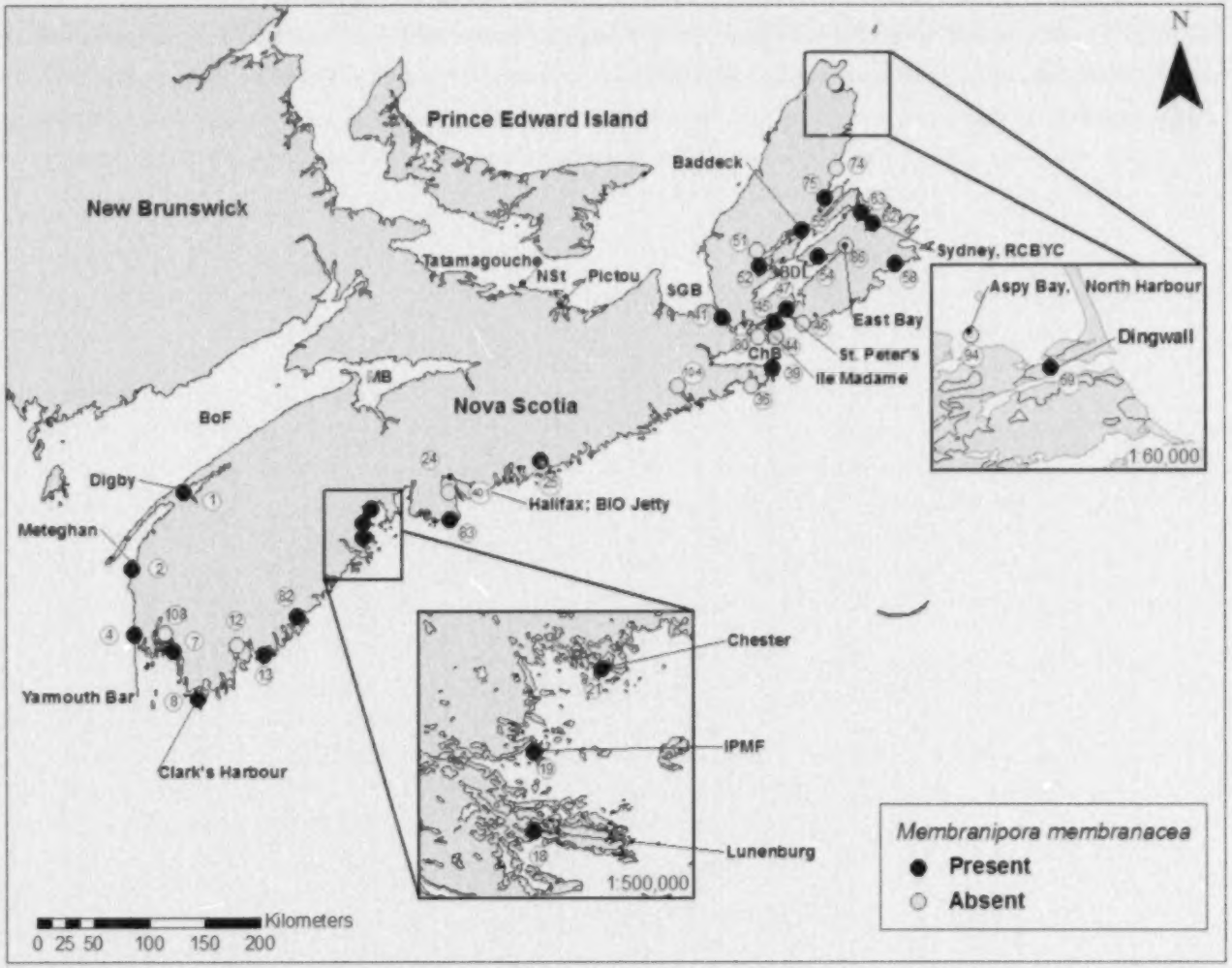


Figure 6: Presence/absence of *Membranipora membranacea* in Nova Scotia in 2011. BoF = Bay of Fundy, ChB = Chedabucto Bay, MB = Minas Basin, NSt = Northumberland Strait, SGB = St. Georges Bay and BDL = Bras d'Or Lake.

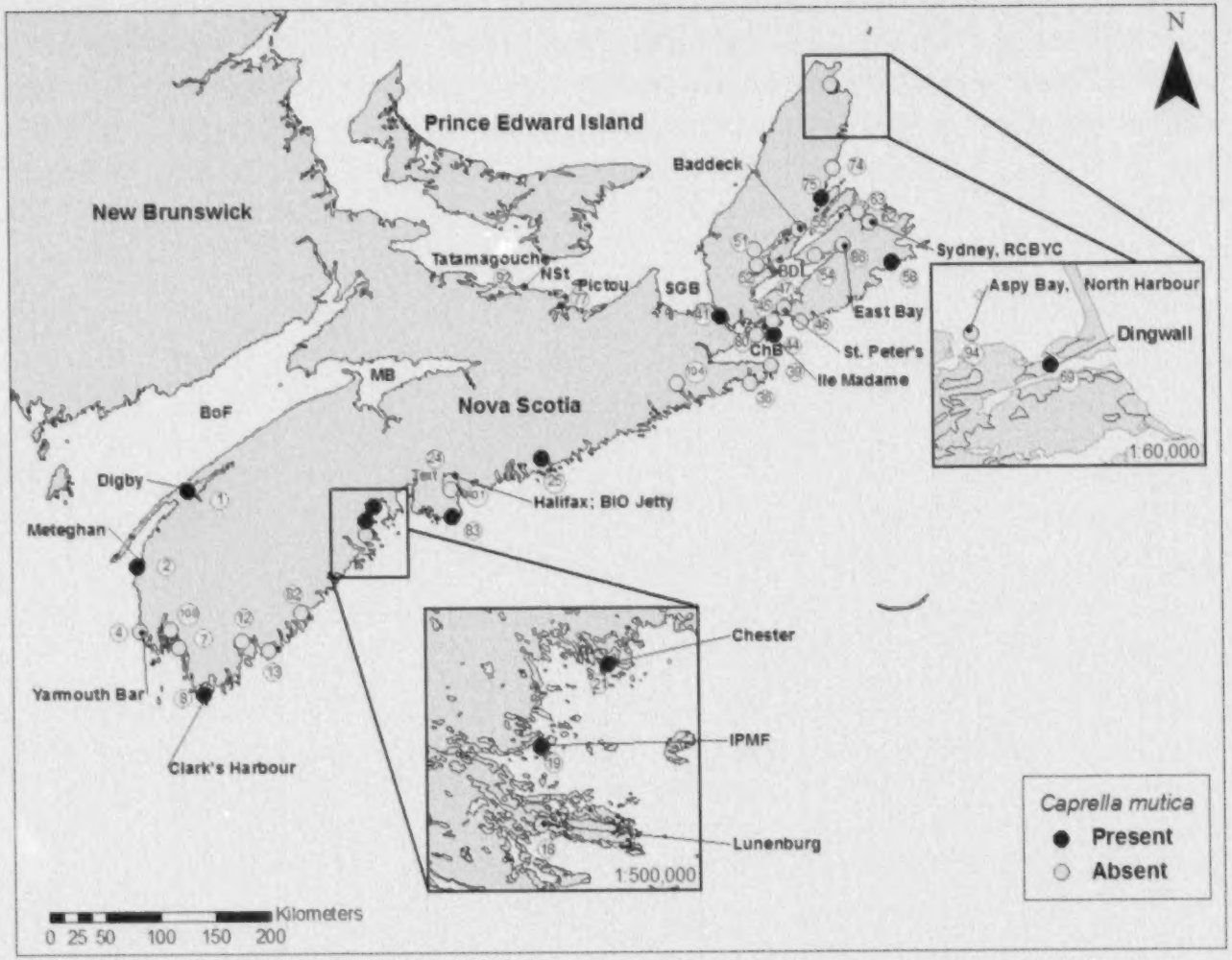


Figure 7: Presence/absence of *Caprella mutica* in Nova Scotia in 2011. BoF = Bay of Fundy, ChB = Chedabucto Bay, MB = Minas Basin, NSt = Northumberland Strait, SGB = St. Georges Bay and BDL = Bras d'Or Lake.

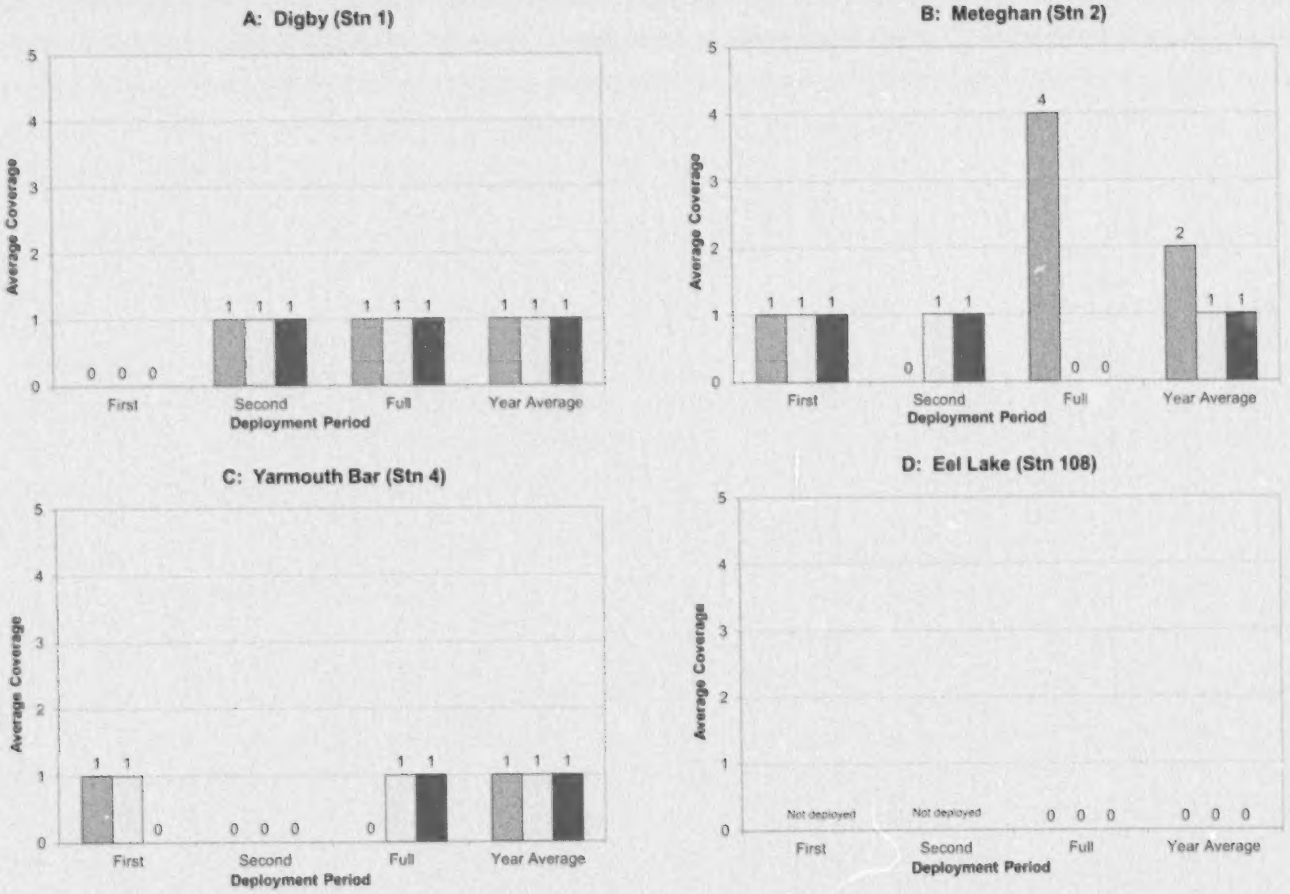


Figure 8 A – D: Seasonal and year average coverage of tunicates on the southwestern shore; Digby (A), Meteghan (B), Yarmouth Bar (C) and Eel Lake (D) in 2011 for *C. intestinalis* ( ), *B. schlosseri* ( ) and *B. violaceus*. ( )

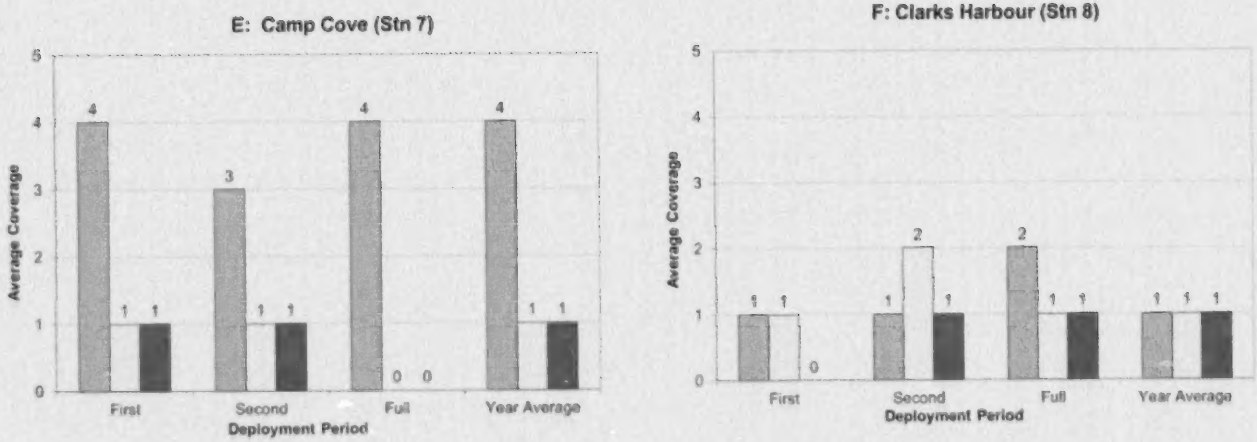


Figure 8 E - F: Seasonal and year average coverage of tunicates on the southwestern shore, continued; Camp Cove (E) and Clark's Harbour (F), in 2011, for *C. intestinalis* ( ), *B. schlosseri* ( ) and *B. violaceus* ( ).

and first and second deployments at Yarmouth Bar (Figure 8C). They were absent on heavily fouled full season collectors at two stations; Camp Cove and Meteghan. Year average coverage was low (1: <25%) at all stations.

Ciona intestinalis was the dominant tunicate in this region, often showing heavier, or earlier, settlement than *B. schlosseri* and *B. violaceus*. Tunicates were not found at Eel Lake in 2011 (Figure 8D)

3.5.2 South shore (Lockeport to Chester)

In terms of a general trend, *C. intestinalis* was variable in its presence and coverage in this region and throughout the monitoring period. It was present at all stations except at Port Mouton (Figure 9C), and on Lease 2 at Indian Point (Figure 9F). It was not found during the first deployment at Chester (Figure 9H), or during the second deployment at Lockeport (Figure 9A) and Lunenburg (Figure 9D). Coverage was heaviest (4: 76-100%) at Shelburne (Figure 9B), during all deployment periods, and on full season collectors at Lunenburg (Figure 9D) and Lockeport. Coverage was variable among the three leases at Indian Point, where moderate (2: 25-50%) coverages were noted on Lease 1 (Figure 9E), low (1: <25%) and moderate during the first and second deployments, respectively on Lease 3 (Figure 9G) and absent from Lease 2 (Figure 9F). Low fouling was noted at Chester (Figure 9H). Heaviest year average coverages (4: 76-100%) were noted at Shelburne followed by moderate coverages at Lockeport, Lunenburg and Indian Point, and low coverages at Chester.

Botryllus schlosseri was present on monitoring plates at some time during the monitoring period at all stations. It was not detected during the first and second deployments at Lockeport (Figure 9A), or during the second deployment at Port Mouton (Figure 9C), or on leases 2 and 3 at Indian Point (Figures 9F and G, respectively). Its absence from full season collectors at Lunenburg and Shelburne was probably the result of heavy coverage by *C. intestinalis* on monitoring plates. Heaviest coverages of this species were noted during the first deployment at Chester (3: 51-75%), when moderate (2: 25-50%) coverages were noted at Lunenburg. Year average coverages were highest at Chester (2: 25-50%), and coverages were low (1; <25%) at all other stations.

Botrylloides violaceus was not detected at Port Mouton (Figure 9C), or during the second deployment at Indian Point, and it was only found on a full season collector rope at Shelburne. When detected, coverage of *B. violaceus* was low (1: <25%) with the exception of Lockeport (Figure 9A) during the first (2: 25-50%), and second (3: 51-75%) deployments. Consequently, the highest year average coverage (2: 25-50%)

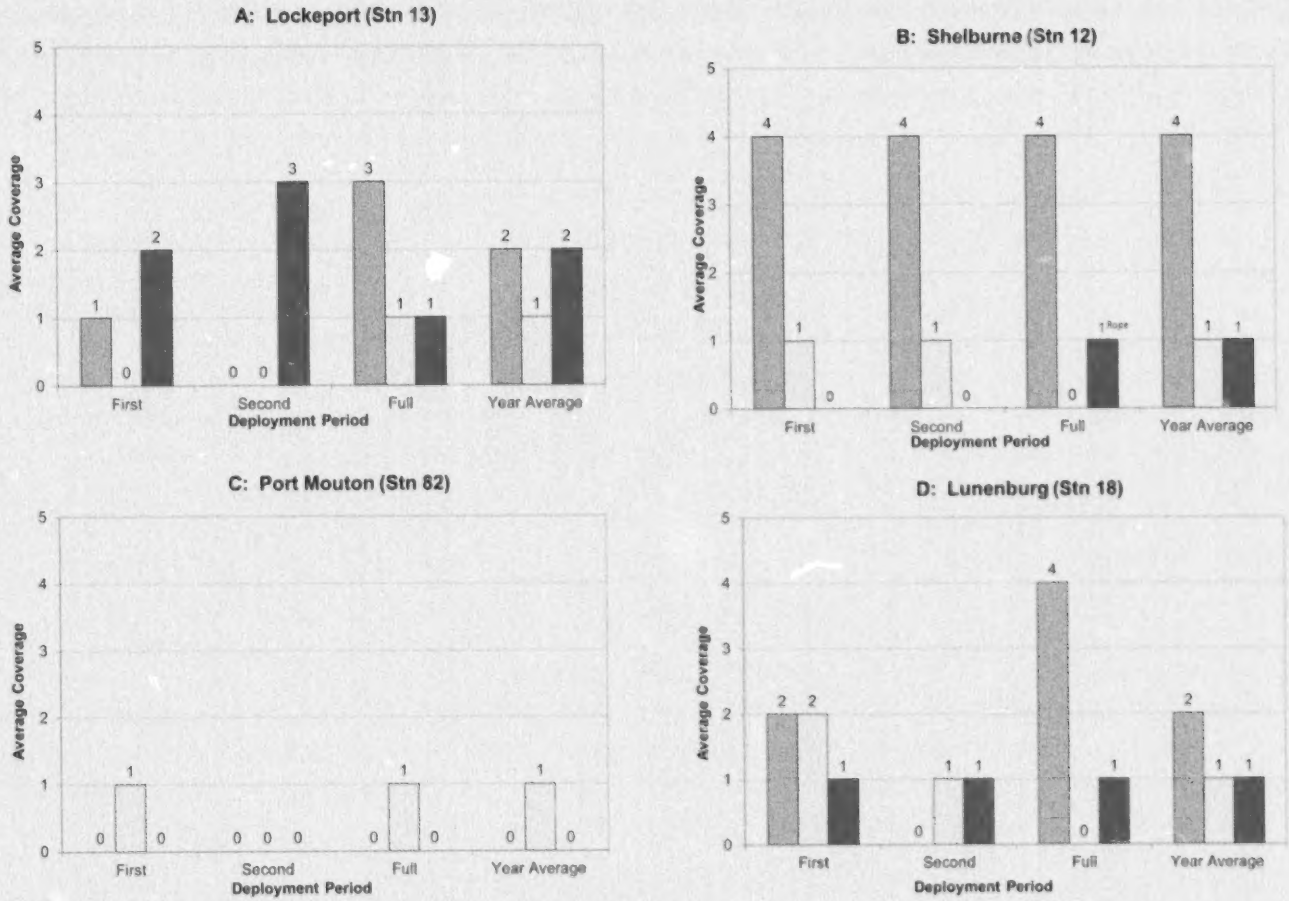


Figure 9A - D: Seasonal and year average coverage of tunicates on the south shore; Lockeport (A), Shelburne (B), Port Mouton (C) and Lunenburg (D) in 2011, for *C. intestinalis* ( ), *B. schlosseri* ( ) and *B. violaceus* ( ).

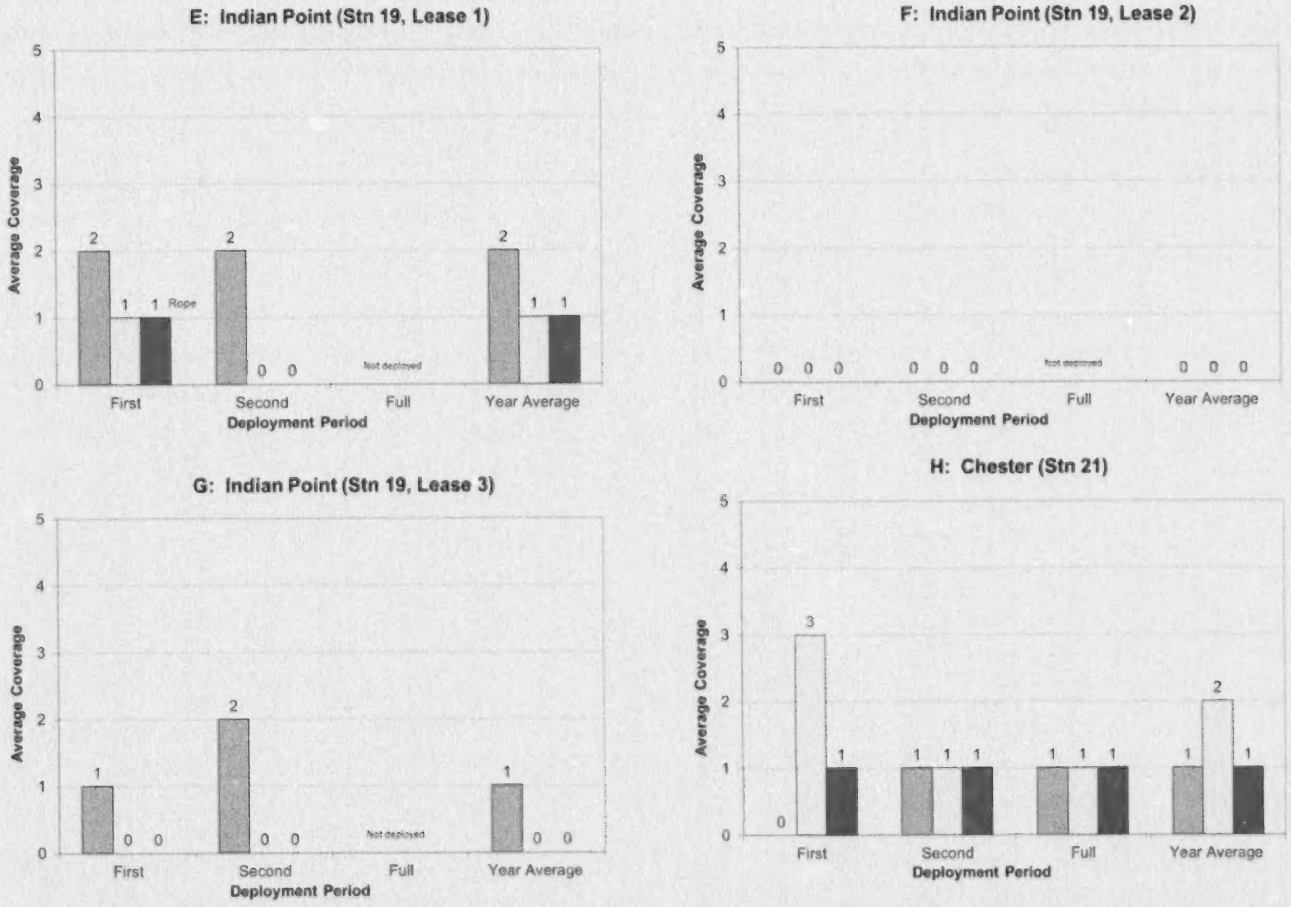


Figure 9E - H: Seasonal and year average coverage of tunicates on the south shore, continued; Indian Point, Lease 1 (E), Indian Point, Lease 2 (F), Indian Point, Lease 3 (G) and Chester, (H), in 2011, for *C. intestinalis* ( ), *B. schlosseri* ( ) and *B. violaceus* ( ).

was noted at this station.

3.5.3 HRM (Halifax Regional Municipality)

Ciona intestinalis was present at both stations monitored in this area: Sambro (Figure 10A) and Halifax: BIO (Figure 10B), and was reported at the Armdale Yacht Club (Figure 2, Appendix 1). At Sambro, *C. intestinalis* completely covered lower and upper plate surfaces of full season collectors, and since collectors were not deployed during other deployment periods, the year average coverage was high (4: 76-100%). At Halifax: BIO, *C. intestinalis* was present on first, second and full season deployment collectors, with the highest coverage during the second deployment (2: 25-50%), and a low (1: <25%) year average coverage.

Botryllus schlosseri was also present at both stations, with low (1: < 25%) coverages observed on monitoring plates during all deployments at Halifax: BIO, and at Sambro. It was also reported at the Armdale Yacht Club (Figure 2, Appendix 1), heavily infesting submerged structures.

Botrylloides violaceus was not detected at Halifax:BIO, or at the Armdale Yacht Club, but was present with low coverage (1: < 25%) at Sambro.

3.5.4 Eastern shore (Ship Harbour to Whitehead)

Tunicates were not found at Ship Harbour, the only station monitored in this region during 2011 (Figure 11A). *Ciona intestinalis* was reported on two mussel aquaculture sites: Country Harbour and Whitehead (Figure 2, Appendix 1).

3.5.5 Chedabucto Bay (Cape Canso to Ile Madame)

Ciona intestinalis was present at all stations monitored in this region during all deployment periods, with the exception of D'Escousse (Figure 12D) where no data were obtained as first deployment plates were lost. Highest seasonal coverages were noted at Petit-de-Grat (Figure 12C), where collectors were heavily (4: 76-100%) fouled during second and full deployments. Coverage was moderate (2: 25-50%) on full deployment plates at Venus Cove (Figure 12B), and low (1: <25%) at Cape Canso (Figure 12A), and D'Escousse. Year average coverages ranged from high (3: 51-75%) at Petit-de-Grat, to low at the other stations. The species was also reported from Robin's Cove, Ile Madame (Figure 2, Appendix 1).

Botryllus schlosseri was present sporadically on monitoring plates in this region. Coverage by this species was low (1: <25) at Cape Canso during the second and full deployment periods, on full season collectors at Venus Cove, and on second deployment period plates at Petit-d-Grat and D'Escousse. Year average coverages for this species were low at all stations.

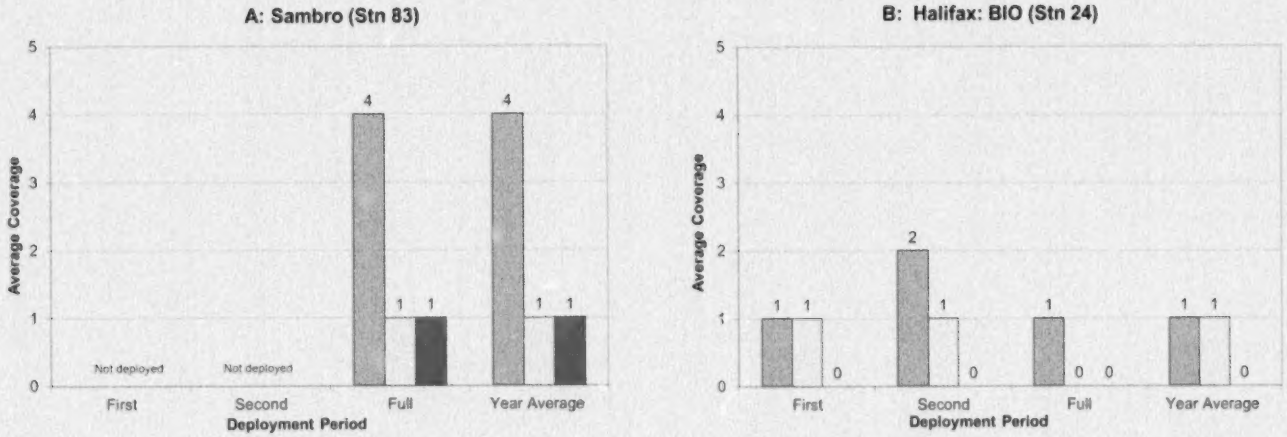


Figure 10A – B. Seasonal and year average coverage of tunicates in the Halifax area; Sambro (A), and Halifax: BIO (B) in 2011, for *C. intestinlais,* ( ) , *B. schlosseri* , ( ) *B. violaceus* ( ).

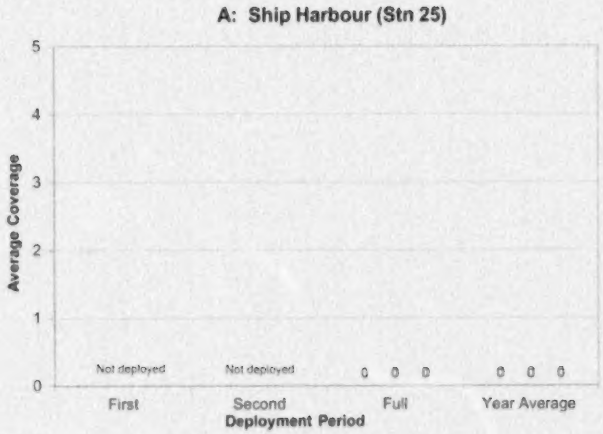


Figure 11: Seasonal and year average coverage of tunicates on the eastern shore: Ship Harbour (A) in 2011 for *C. intestinalis* ( ), *B. schlosseri* ( ) and *B. violaceus* ( ).

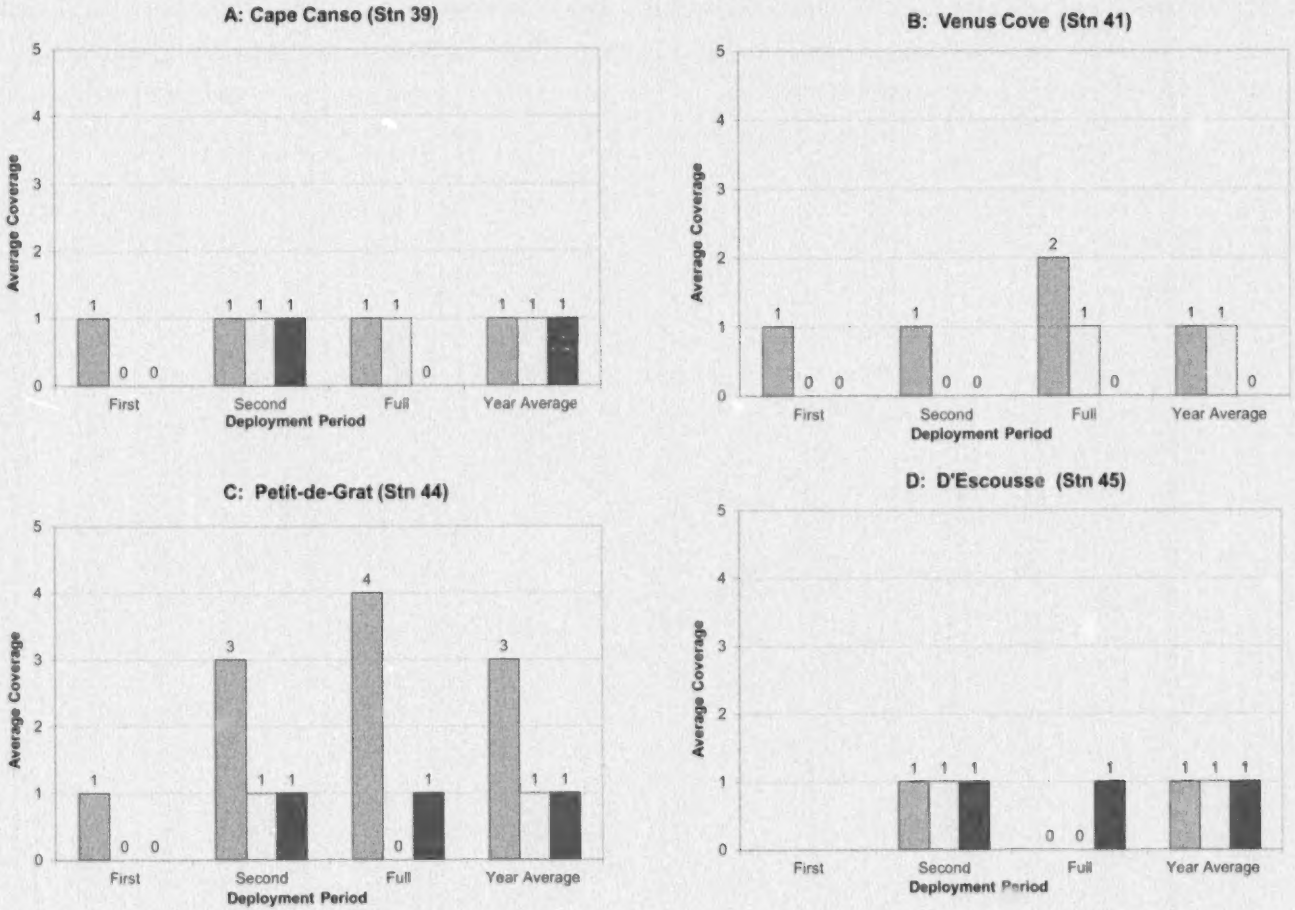


Figure 12A – D: Seasonal and year average coverages of tunicates in Chedabucto Bay; Cape Canso (A), Venus Cove (B), Petit-de-Grat (C) and D'Escousse (D) in 2011 for *C. intestinalis* ( ), *B. schlosseri* ( ) and *B. violaceus* ( ).

3.5.6 Cape Breton

Ciona intestinalis was present during all deployments at Louisbourg (Figure 13A), on first and second deployment collectors in Sydney (Figure 13B), where it was the only tunicate species detected, and during the first deployment period only at North Sydney (Figure 13C). It was present at Dingwall (Figure 13F) where only full season collectors were deployed. Year average coverages were highest at Louisbourg (2: 25-50%), and low (1: <25%) at Sydney, North Sydney and Dingwall. Vase tunicates were also reported at Little Harbour (Figure 2, Appendix 1).

Botryllus schlosseri showed low (1: <25%) to moderate (2: 25-50%) coverages at Louisbourg (Figure 13A), North Sydney (Figure 13C), Little River (Figure 13D), where it was the only tunicate species detected, and Dingwall (Figure 13F). It was not detected at Louisbourg or North Sydney until the second deployment, but was present during all deployment periods at Little River. Highest coverages were noted at Louisbourg and Little River. Year average coverages were highest at Little River (2: 25-50%), and low at Louisbourg, North Sydney and Dingwall. The species were also reported at Little Harbour (Figure 2, Appendix 1).

Botrylloides violaceus was only found at two stations in this region: North Sydney (Figure 13C) where it was found throughout the monitoring period, and at Dingwall (Figure 13F). Year average coverage was highest at North Sydney (2: 25-50%), and low at Dingwall. *Botrylloides violaceus* was also reported at Little Harbour (Figure 2, Appendix 1).

Tunicates were absent from one station monitored in this region: St. Ann's Bay (Figure 13E) and also from Aspy Bay, North Harbour, both active mussel aquaculture sites. Tunicate fouling was not dominated by a single species in this region. Heaviest fouling by *C. intestinalis* was noted at Louisbourg, while *B. violaceus* was the dominant tunicate at North Sydney. Only *C. intestinalis* was detected at Sydney, while only *B. schlosseri* was present at Little River.

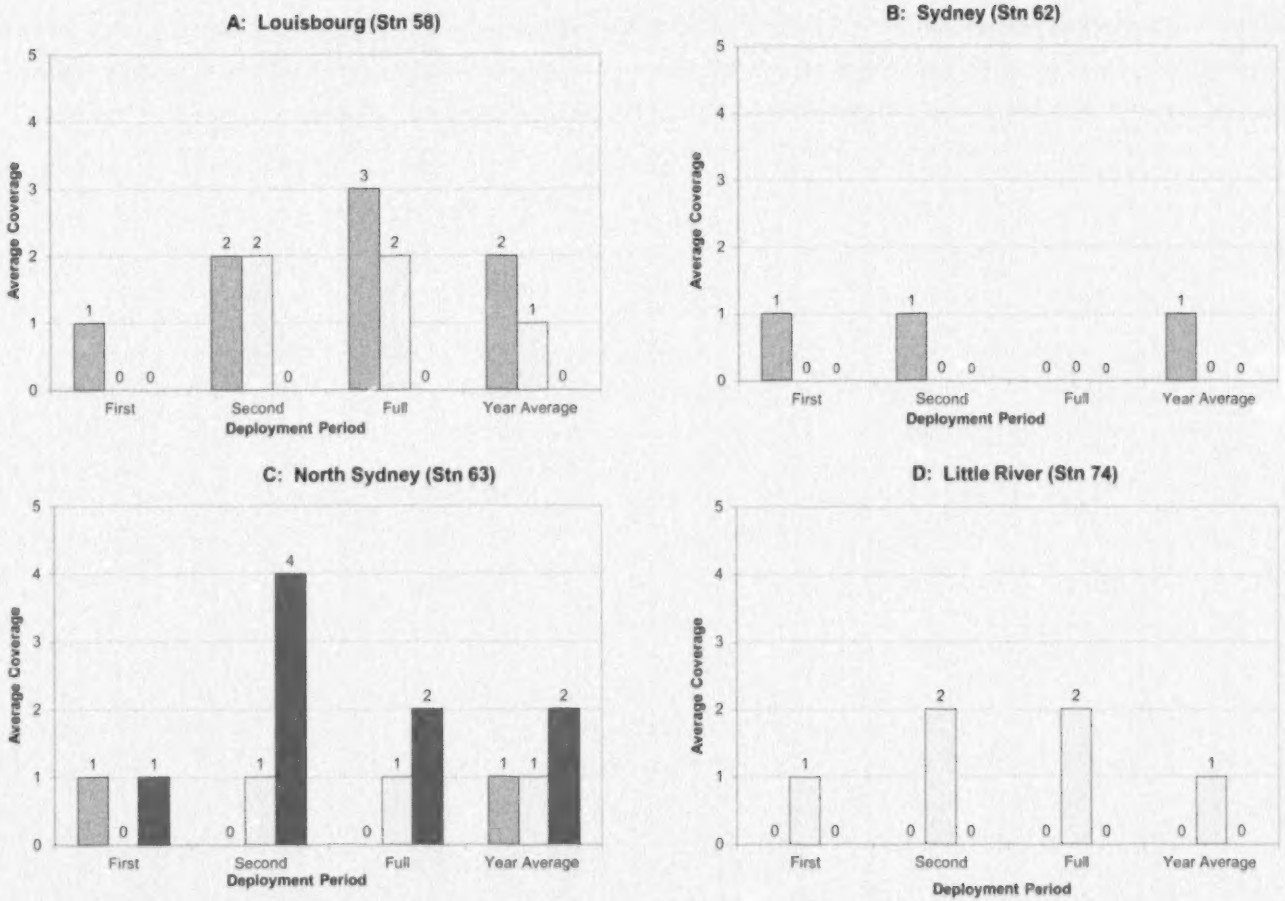
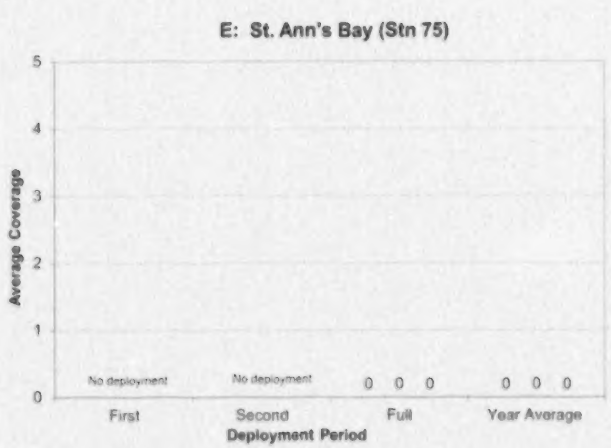


Figure 13A – D: Seasonal and year average coverages of tunicates in Cape Breton: Louisbourg (A), Sydney (B), North Sydney (C) and Little River (D) in 2011. for *C. intestinalis* ( ), *B. schlosseri* ( ) and *B. violaceus* ( ).



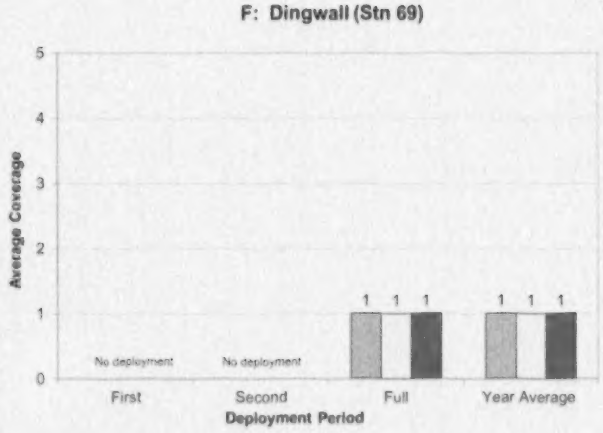


Figure 13 E – F. Seasonal and year average coverage of tunicates in Cape Breton, continued; St. Ann's (E) and Dingwall (F) in 2011, for *C. intestinalis* ( ), *B. schlosseri* ( ) and *B. violaceus* ( ).

3.5.7 Bras d'Or Lake

Ciona intestinalis was detected in very low numbers on second and full season monitoring collectors at one location in this region; St. Peter's (Figure 14A).

Botryllus schlosseri was present at five of six monitoring stations in the Bras d'Or Lake in 2011; no tunicates were found at Orangedale (Figure C). Golden star tunicates were present during all deployment periods at Whycocomagh (Figure 14B) and Eskasoni (Figure 14E), during the second and full deployments at St. Peter's (Figure 14A), during the second deployment at Baddeck (Figure 14D) and on full season collectors deployed at East Bay (Figure 14F). Coverage was highest at St. Peter's, with heavy (3: 51-75%) coverages on second and full deployment plates, followed by Eskasoni and Whycocomagh, where coverage was moderate (2: 25-50%) during the second deployment. Unfortunately, first and full season collectors could not be deployed at Baddeck due to winter storm damage to the dock, so it was not possible to determine whether *B. schlosseri* settled at this location early in the season. Year average coverage was highest at St. Peter's (2: 25-50%), and low (1: <25%) at all other stations.

Botrylloides violaceus was not detected in this region in 2011.

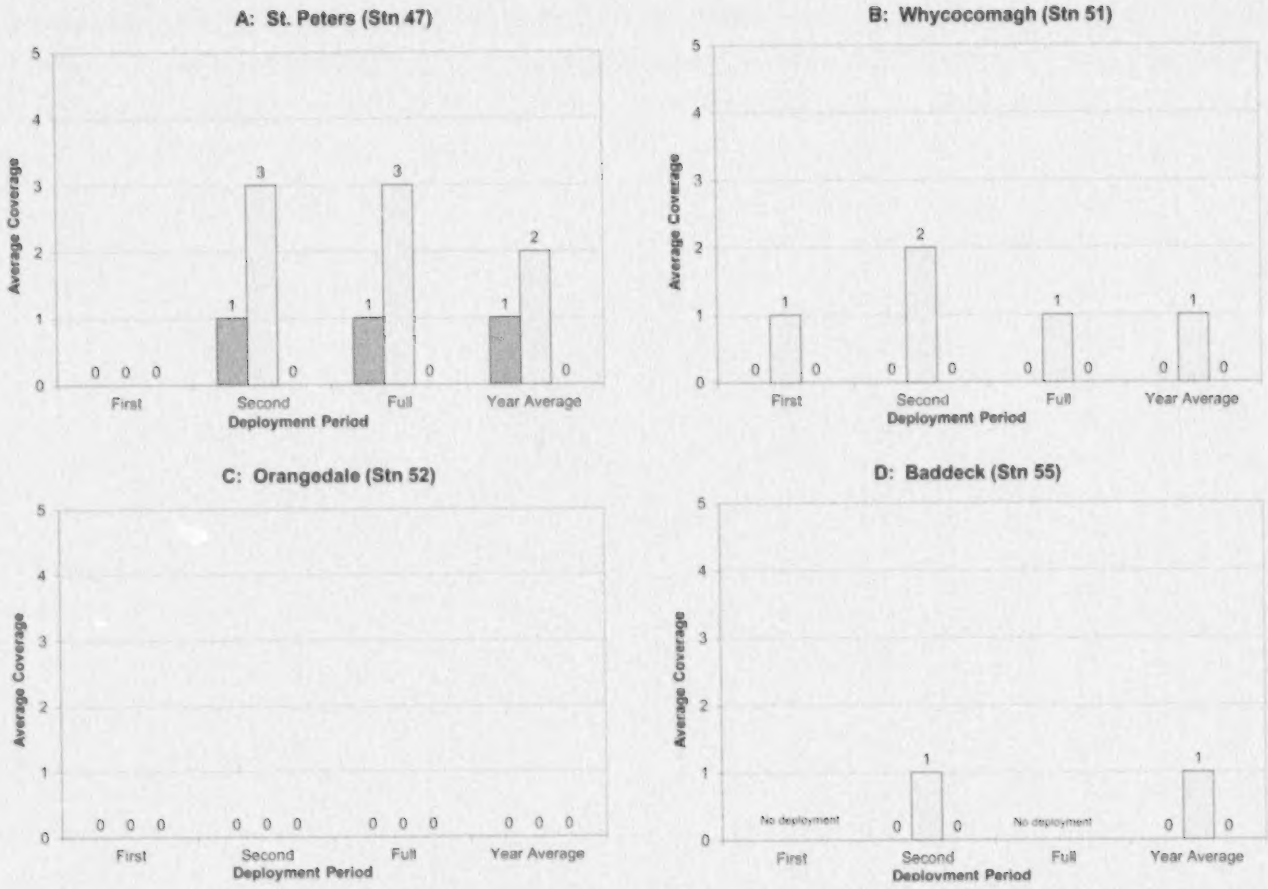


Figure 14 A - D: Seasonal and year average coverage of tunicates in Bras D'Or Lake; St. Peter's (A), Whycocomagh (B), Orangedale (C) and Baddeck (D) in 2011 for *C. intestinalis* (■), *B. schlosseri* (□) and *B. violaceus* (■).

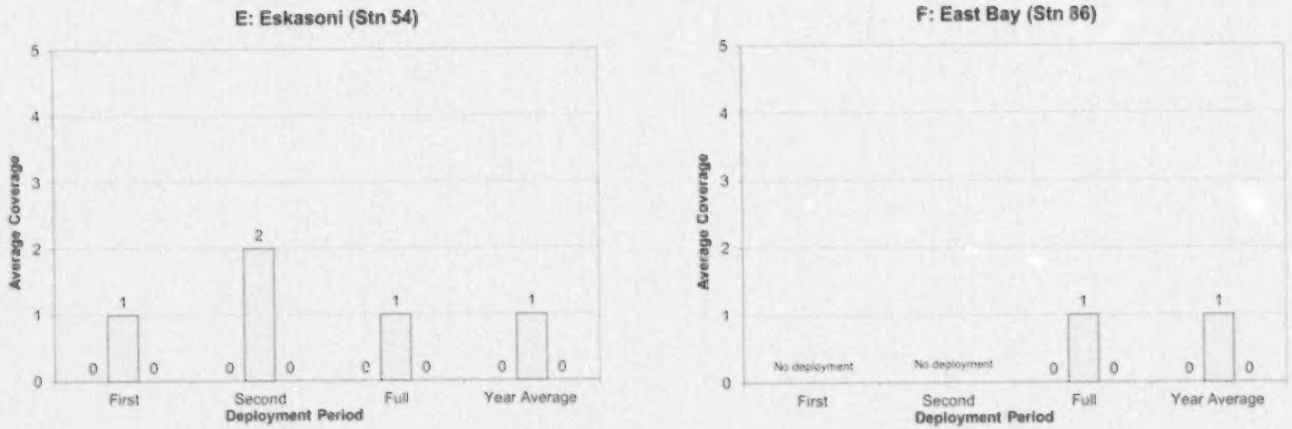


Figure 14 E – F: Seasonal and year average coverage of tunicates in Bras D'Or Lake, continued; Eskasoni (E) and East Bay (F) in 2010 for *C. intestinalis* ( ), B. *schlosseri* ( ) and *B. violaceus* ( ).

4.0 DISCUSSION

4.1 TUNICATE ESTABLISHMENT AND SPREAD

The results of the 2011 DFO monitoring in Nova Scotia, and previous monitoring conducted between 2006 to 2010 (Sephton et al. 2011, 2014), indicate that populations of *C. intestinalis*, *B. schlosseri* and *B. violaceus* are well established in many locations. Beyond the presence of a suitable vector for introduction and spread, the establishment of non-indigenous tunicates, and other AIS, depends upon the suitability of the receiving environment (Locke 2009). Temperature and salinity values recorded during visits to coastal monitoring stations in 2011 were within the tolerance ranges of these tunicate species (Carver et al, 2006 a,b; Eppelbaum et al. 2009, Vercaemer et al. 2011, Therriault and Herborg 2007), so there is potential for spread to new locations.

Only the north shore of the province bordering on Northumberland Strait was thought to be free of tunicates up until 2011 (Sephton et al. 2014; Bernier, pers. comm), but *B. schlosseri* was reported at Tatamagouche in 2011 (http://www.isdm-gdsi.gc.ca/ais-eae/getSpeciesGeo-obtenirEspeceGeo.do?data_id=18749&lang=en). This species was previously reported at Cribbon's Point and Ballantyne's Cove in St. George's Bay (Figure 2) in 2009 (Lacoursière-Roussel, pers. comm.) and again in 2011 (R. Bernier, pers. comm). *Ciona intestinalis* was reported in Auld's Cove in 2005 (R. Bernier, pers. comm), and at Havre-Boucher in 2008 and 2009 (Sephton et al. 2011). These sporadic reports of a few colonies or individuals may indicate spread from Chedabucto Bay, an area with a high volume of recreational and international commercial vessel traffic (Lacoursière-Roussel et al. 2012a; Lo et al. 2012) through the Canso Canal, or from nearby PEI (Darbyson et al. 2009).

There are still sites throughout the province that appear to be tunicate free, however. Tunicates were not detected at three shellfish aquaculture sites; St. Ann's and Aspy Bay, North Harbour in Cape Breton, and Ship Harbour on the eastern shore in 2011, probably due to concerted efforts to prevent their introduction through aquaculture transfers, and through local outreach and education efforts to inform fishers and boaters of the threats posed by tunicate introduction.

Biofouling monitoring results (Figure 2) for 2011 were consistent with earlier monitoring results (Sephton et al. 2011, 2014). Namely;

- The southwestern and south shores and Ile Madame, in Chedabucto Bay, are long-established "hot-spots" for *C. intestinalis*, while low to moderate coverages of *B. schlosseri* and *B. violaceus* are noted at many sites. Indeed, *C. intestinalis*

was the dominant tunicate in these regions in 2011, with lower coverages of colonial tunicates.

- *Ciona intestinalis* and *B. schlosseri* are well established in the port of Halifax and surrounding areas, where *C. intestinalis* dominates in several marinas (Vercaemer and Sephton 2014).
- Colonial tunicates continue to be reported sporadically on the eastern shore (Lacoursière-Roussel et al. 2012a), and *C. intestinalis* is now established on shellfish aquaculture sites in Country Harbour and Whitehead areas, and at Port Bickerton.
- The coast of Cape Breton is characterized by the presence of one or more of *C. intestinalis*, *B. schlosseri* or *B. violaceus*, and the dominant species, as well as its coverage, can vary from year to year.
- *Botryllus schlosseri* is the dominant tunicate in the Bras d'Or Lake, with sporadic reports of *C. intestinalis* at the southern entrance to the lake at St. Peter's only, and no reports of *B. violaceus* to date.

There were three first reports of tunicate species at new monitoring sites in 2011: *C. intestinalis* at Louisbourg, *B. schlosseri* at Little River, and *C. intestinalis*, *B. schlosseri* and *B. violaceus* at Sambro. It is possible *C. intestinalis* was present at Louisbourg in 2010, given its moderate infestation in 2011. It was not detected there up to 2009, but collectors were lost in 2010, so no information was obtained. It is also possible that *B. schlosseri* has been present for some time in Little River, given its dominance nearby in the Bras d'Or Lake. Similarly, *C. intestinalis*, *B. schlosseri* and *B. violaceus*, have likely been present at Sambro, at the approach to the port of Halifax, for some time.

4.1.1. *Ciona intestinalis*

Information from sentinel stations (key stations monitored in all, or most years; Table 6) shows that, despite some inter-annual variability due to differing numbers of stations and locations monitored, *C. intestinalis* has increased its presence from 2006 (52%) to 2011 (66%) at sentinel stations (Table 6), with heavier coverage noted at four stations in 2011 (Camp Cove, Shelburne, Lunenburg and Louisbourg). It is now established in Digby, from Country Harbour to Canso, and in Dingwall and Louisbourg. It has not established in the Bras d'Or Lake, probably due to low salinities, although a few individuals have been noted sporadically in St. Peter's. This site may be subject to annual introductions through St. Peter's Canal from the Isle Madame "hot spot", or other regions, or there may be a very small, aggregated population that is difficult to detect consistently by the current monitoring protocol. The north shore is also at risk of

Table 6: Year average prevalence of *Ciona intestinalis*, *Botryllus schlosseri* and *Botrylloides violaceus* at sentinel stations in NS in 2006 through 2011. nm= not monitored, P = present. Categories for the percentage cover were: 0: (absent), 1: <25% (low), 2: 25-50% (moderate), 3: 51-75% (heavy), and 4: 76-100% (very heavy). Red and green lines indicate increasing and decreasing abundance trends, respectively. * = DFO Gulf station.

Region	Sentinel Station	*Ciona intestinalis*						*Botryllus schlosseri*						*Botrylloides violaceus*					
		2006	2007	2008	2009	2010	2011	2006	2007	2008	2009	2010	2011	2006	2007	2008	2009	2010	2011
SW Shore	Digby	1	0	1	1	1	1	1	1	1	1	1	1	0	0	0	0	1	1
	Meteghan	2	1	2	2	2	2	1	1	1	1	1	1	0	1	1	1	1	1
	Yarmouth Bar	1	0	0	1	1	1	1	0	0	1	1	1	0	0	1	1	1	1
	Wedgeport	1	1	1	2	3	nm	1	2	2	1	1	nm	1	1	2	1	1	nm
	Camp Cove	1	3	3	3	2	4	1	1	1	1	1	1	1	1	1	1	1	1
	Clark's Harbour	nm	3	1	3	1	1	nm	1	1	1	1	1	nm	1	1	1	1	1
S Shore	Shelburne	nm	3	2	1	2	4	nm	1	1	1	1	1	nm	1	0	0	0	1
	Lunenburg	1	4	4	2	1	2	1	1	1	1	2	1	1	1	1	1	1	1
	Indian Point	2	4	4	4	2	2	1	1	2	1	1	1	0	1	1	1	1	1
	Chester	3	1	1	1	1	1	1	1	2	3	2	2	0	1	1	1	1	1
Halifax	Halifax BIO	1	1	1	2	0	1	0	0	1	1	0	1	0	0	0	0	0	0
E Shore	Ship Harbour	nm	0	nm	0	0	0	nm	0	nm	0	0	0	nm	0	nm	0	0	0
Chedabucto	Venus Cove	nm	nm	1	2	1	1	nm	nm	1	1	1	1	nm	nm	0	0	0	0
	Petit de Grat	0	nm	4	3	P	3	1	nm	1	1	P	1	1	nm	1	1	P	1
Bras D'Or	St Peters	0	1	1	1	0	1	1	2	3	1	3	2	1	0	1	0	0	0
	Whycocomagh	0	0	0	0	0	0	0	0	4	3	3	1	0	0	0	0	0	0
	Eskasoni	0	0	0	0	0	0	1	1	0	1	2	1	0	0	0	0	0	0
	Baddeck	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0
CB Coast	Louisbourg	0	0	0	0	0	2	1	1	1	1	1	1	0	0	0	0	0	0
	Sydney	1	1	0	1	2	1	0	1	1	2	1	0	0	0	0	0	0	0
	North Sydney	nm	1	1	2	2	1	nm	1	1	1	1	1	nm	1	0	1	2	2
	Cheticamp*	0	0	1	0	0	0	1	2	2	2	2	P	1	1	1	1	1	P
	Mabou*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
N Shore	Pictou*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Presence	10	12	15	16	14	16	14	16	19	22	21	19	6	10	11	12	12	12
	# Stations	19	22	23	24	24	24	19	22	23	24	24	24	19	22	23	24	24	24
	%	52	54	65	66	58	66	73	72	82	92	88	79	31	45	47	50	50	50

invasion by *C. intestinalis*, given its presence in St. George's Bay (Sephton et al. 2011) and Auld's Cove (Bernier, pers. comm.) and the volume of vessel traffic from PEI to this area (Darbyson et al. 2009).

4.1.2 *Botryllus schlosseri*

Botryllus schlosseri is the most widely distributed tunicate; present in generally low to moderate coverage at 69 to 84% all records between 2006 and 2009 (Sephton et al. 2011), and at 82% and 88% of all monitoring and sentinel stations, respectively in 2010 (Sephton et al. 2014). In 2011, it was present at 85% of all monitoring stations and 79% of sentinel stations (Table 6). Spread of this species onto the north shore was first noted in 2011. While *B. schlosseri* dominated with heavy coverages in the Bras D'Or Lake between 2008 and 2010, lighter coverages were noted there in 2011, and also at Lunenburg and Chester on the south shore, possibly due to lower summer water temperatures recorded in 2011 (see below). This species was not recorded at Sydney in 2011.

4.1.2 *Botrylloides violaceus*

While *B. violaceus* has spread to a few new locations every year since 2006; (19% to 42% of monitoring stations in 2006 and 2010 respectively; Sephton et al. 2011; 2014), there was no evidence of further spread from 2010 to 2011. Present at 50% of sentinel stations in 2011 (Table 6), it was only noted at one new location, Sambro, where it has likely been present for some time. It was present in Digby for the second consecutive year, and re-appeared in Shelburne. Generally, this species occurs in low coverage in Nova Scotia, but moderate coverages were noted in Lockeport and again in North Sydney in 2011, where it was the dominant tunicate species.

4.1.3 Absence of *Styela clava, Didemnum vexillum, Diplosoma listerianum* and *Ascidiella aspersa*

Four additional tunicate species on the DFO Maritimes Region "watch-list" (Locke 2009): *S. clava, D. vexillum, D. listerianum* and *A. aspersa*, either present in nearby waters of PEI and/or along the coast of the Gulf of Maine, were not detected in NS in 2011. Given the existence of multiple vectors of introduction, and the environmental similarities between donor regions and NS waters (Clarke and Therriault, 2007; Daniel and Therriault, 2007; Therriault and Herborg 2007; McKenzie 2011a, b), these species will likely establish if introduced (Locke 2009).

Primary introductions of NIS in Atlantic Canada may be attributed mainly to the commercial vessel vector (Sylvester et al. 2011; DiBacco et al. 2012; Lacoursiere-Roussel et al. 2012a; Lo et al. 2012; Frey et al. 2014). Halifax Harbour, with its high volume of international traffic (Frey et al. 2004; Kelly 2004), and nine recreational marinas (Vercaemer and Sephton 2014), is the largest and busiest port in Nova Scotia. Smaller ports, such as Yarmouth, Point Tupper (Chedabucto Bay) and Sydney have been identified as important sites of introduction for *B. schlosseri* (Lacoursiere-Roussel et al. 2012a), as have the high traffic recreational marinas on the south shore (Mahone Bay and Chester) and in the Bras d'Or Lake (St. Peter's and Baddeck). *Styela clava* may be introduced to Nova Scotia on boat hulls as recreational and commercial boats regularly travel from PEI to Nova Scotia (Darbyson et al. 2009; Locke et al. 2009). Secondary factors of introduction include rafting attached to floating debris or plants (Carmen et. al. 2014), as floating fragments (Lengyel et al. 2009; Paetzold and Davidson 2010) and through aquaculture transfers (McKindsey et al. 2007; Therriault and Herborg 2007). Introduction as floating fragments is of concern for botryllids (Paetzold and Davidson 2010) and *D. vexillum*, which can re-attach to natural (eelgrass and rocky substrate) and artificial substrates (Carman et al. 2014) at temperatures as low as 6–10°C. Aquaculture transfers are not thought to be an important vector in NS, however, as the industry is small, most culture sites are far from marinas and large harbours, transfers are carefully regulated by a DFO Introductions and Transfers Committee and stock and gear must be cleaned prior to movement between locations (Lacoursiere-Roussel et al. 2012a).

Three new tunicate invaders to Nova Scotian waters were reported in 2012 in two areas mentioned above, however. *Styela clava*, *D. listerianum* and *A. aspersa* were reported in Luneburg Harbour, on the south shore, while *S. clava* was reported in Halifax Harbour (Vercaemer et al. 2012; Moore et al. 2014), both areas subject to primary introduction by commercial vessel shipping. *Didemnum vexillum*, however, was also recorded for the first time in Atlantic Canada in 2013 in the Minas Basin, upper Bay of Fundy (Moore et al. 2014), an area with limited international traffic and no recreational marinas, although commercial barges from outside the Bay have visited the area recently to deliver and install infrastructure at the Fundy Ocean Research Centre for Energy (FORCE) (A. Redden, pers comm.) There is also a small commercial sea scallop (*Placopecten magellanicus*) fishery in the upper Bay, with vessel movement into the area from the mid and outer Bay, and from several home ports of the offshore fishery (Scotia Shelf) (J. Sameoto, pers. comm), so it is possible that the species was introduced through fragments in fishing gear. Given the strong current and tidal activity in the upper Bay of Fundy (Wu et al. 2011), floating fragments in ocean currents must also be considered as a potential vector for the introduction as well, as colonies dislodged from the bottom by scallop dragging may enter non-infested areas and

reattach on hard substrates (Bullard et al. 2007; Carman et al. 2014). Lengyel et al. (2009), however, contend that *D. vexillum* fragments dislodged by dredging on George's Bank have the potential to disperse only about 20 km before re-attaching to the substrate, so this is an unlikely source of primary introduction to the upper Bay of Fundy.

4.2 SPATIAL AND TEMPORAL VARIATION IN TUNICATE DISTRIBUTIONS

Tunicate distributions in Nova Scotia have previously been described as discontinuous or "patchy" in space and "sporadic" in time (Sephton et al. 2011) and these characteristics were again evident in 2011.

4.2.1 Spatial Variations

Small scale "patchiness" was evident at many sites, where different monitoring plates on the same collector (Collector 6, Clark's Harbour, Appendix 1), or different collectors deployed at different areas on a station during the same deployment period (Collector's 1 and 2 , Lunenburg, Appendix 1), showed differences in coverage of tunicates. Limited natural dispersal of tunicates larvae (Lambert and Lambert 1998, Lambert 2005) or aggregated larval settlement (Osman and Whitlatch 1995) may account for small scale variation in settlement and biofouling observed on monitoring plates. Low current environments are prefered by many tunicate species, so dispersal by circulating tidal waters may be limited. This may explain the absence of tunicates on monitoring plates on Lease 2 at Indian Point in 2011, as tunicates were indeed present on this site on nearby mussel lines (P. Darnell, pers. comm). They were also present nearby on Lease 1, with comparable current and environmental conditions (P. Darnell, pers. comm.), and where settlement on monitoring plates approximated the degree of tunicate biofouling on the mussel lines.

"Stepping-stone" type introductions of tunicates may occur from bay to bay as a result of movement of small vessels with fouled hulls. Lacoursiere-Rousel (2012b) found that about 49% of recreational boats examined in Nova Scotia in 2010 were fouled by tunicates (*C. intestinalis*, *B. schlosseri* and *B. violaceus*), and that 89% of small boats visited marinas other than their home ports during summer or fall, which could greatly facilitate tunicate colonization in new areas. The absence of of *C. intestinalis* at Port Mouton, a small fishing harbour on the south shore monitored since 2009 close to other small harbours where the species is present, could also be explained by the lack of a marina to attract recreational vessels from neighboring ports and harbours.

Another type of spread from adjacent bays or different regions of the same bay may occur through the use of intermediate settlement nodes. Kanary et al. (2011) investigated the sporadic appearance of *C. intestinalis* in Charlottetown Harbour, PEI, and its non-establishment in nearby waters and used a matrix population model in conjunction with an oceanographic model to predict its appearance in nearby waters. They determined that advection of larvae to new areas requires more than one or two generations, and settlement on navigational aids or other structures to achieve "stepping stone" introductions.

4.2.1 Temporal Variations

While the coverage of *C. intestinalis*. *B. schlosseri* and *B. violaceus* on monitoring plates varied throughout the year at many stations, some seasonal patterns were evident.

Highly successful overwintering ability, and dominance by *C. intestinalis* was noted as heavy coverages during the first deployment period at Camp Cove (southwest NS), and Shelburne and Indian Point (south shore). The spawning period for this species in Nova Scotia begins in late May, or when water temperatures reach ~8°C, regarded as the lower limit for spawning in Nova Scotian populations (Carver et al., 2006a), and continues through until November or early December (Vercaemer et al. 2011; Appendix 3). Larvae may grow quickly following settlement (Carver et al. 2003), leaving little room for colonial tunicates, which may explain their absence or low coverages on plates at Shelburne. Vase tunicates were absent during the first deployment period at Digby in 2011, the coldest station (Appendix 3), and also at St. Peter's, and the increased coverages observed during the second deployment period at Halifax, Petit-de-Grat and Louisbourg may reflect increased settlement due to increasing water temperature. Given their sporadic presence in St. Peter's, however, their appearance during the second deployment may also be a new introduction, or the presence of very small or aggregated population which was not detected by the current monitoring protocol.

Settlement and growth by colonial tunicates later in the season when waters are warmer (Chadwick-Furman and Weissman 1995; Epelbaum et al. 2009) may be reflected by the first deployment absence of *B. schlosseri* in Digby, Lockeport, Petit-de-Grat, Cape Canso, Venus Cove, Louisbourg and North Sydney, and *B. violaceus* in Digby, Yarmouth Bar, Cape Canso and Petit-de-Grat. Colonial tunicates were most abundant during the second deployment period at Lockeport, Little River (*B. schlosseri* only) and North Sydney. In Bras d' Or Lake, however, the absence (Orangedale) or lower coverages of *B. schlosseri* at many stations in 2011 compared with 2010

(Sephton et al 2014) may reflect the cooler water temperature observed in 2011, although temperature data were obtained from only one station in this region; Eskasoni, in 2011.

Anomalies in seasonal patterns of settlement, such as were observed at Lockeport (Figure 9A), where vase tunicates were not found on second deployment collectors, and golden star tunicates only found on full season collectors, or at Yarmouth Bar (Fig 8B) where tunicates were not present on second deployment collectors, may reflect very small populations or aggregated settlement at small scales. It is important that replicate monitoring collectors are deployed in different areas during different deployment periods to ensure that the overall settlement pattern is reflected accurately, and "false-negative" results are not reported. At locations where multiple biofouling species are present, the dominant species may foul collector plate surfaces first, reducing or eliminating attachment surfaces for other species. The use of additional AIS detection methods, such as a visual inspection of submerged structures, at new locations or sites with suspected low infestations may also help in the clarification of seasonal settlement patterns.

Year-to-year patchiness in the presence and coverage of tunicate species was also noted at several sentinel stations (Table 6), and may reflect changing environmental conditions, especially temperature and salinity, from year-to-year. Vercaemer et al. (2011) tracked air and water temperature changes and subsequent recruitment of *C. intestinalis* larvae and degree of infestation at Indian Point Marine Farms (Station 19) from 2003 to 2010, and found that cooler winters, followed by cooler summers, resulted in lower infestations of *C. intestinalis,* while much higher infestations were observed during warmer summers following warmer winters. Comparison of spring through fall water temperatures recorded in 2010 and 2011 can only be made at four monitoring stations: Digby, Indian Point, Aspy Bay (North harbour) and Eskasoni. These are located in four regions of NS: southwest and south shores, northern Cape Breton coastal and Bras d'Or Lake, respectively, and comparisons of water temperature maxima and trends may be cautiously inferred in each of these regions.

No consistent effect of changes in water temperature regimes from 2010 to 2011 on tunicate coverages on the southwestern and south shores cost of Nova Scotia were evident, however. Temperature data from Digby, one of the coldest stations, showed that 2010 and 2011 were comparable years, with a similar pattern of heating and cooling and a maximum summer water temperature of ~16°C, There was a brief period of warming in mid to late June in 2010, however that was not observed in 2011. This may explain the presence of *C. intestinalis* in Digby during the first deployment period of 2010, but not in 2011. Overall, however, tunicate coverages in this region were

comparable in both years, with the exception of Camp Cove, an inland, sheltered station, where a much heavier infestation of *C. intestinalis* was noted in 2011 (Table 6). Temperature data from Indian Point (Site 2), showed a warmer temperature regime in 2010 compared with 2011. There were two peaks in water temperature in 2010; a weak peak of ~17°C in mid- July, followed by longer peak at ~20°C in early September. Temperature slowly peaked at 19°C in early September in 2011. Two stations in this region; Indian Point and Chester, showed comparable tunicate coverages in 2010 and 2011, while increases in the coverage of *C. intestinalis* were noted at Shelburne and at Lunenburg.

In Cape Breton, differences in tunicate coverages were more clearly linked to differences in water temperature between 2010 and 2011. In coastal Cape Breton, water temperature peaked earlier (late August) and was higher (22°C) in 2010 compared with 2011, with an early-mid September peak of 20°C. This may explain the lower coverages of *C. intestinalis* at Sydney and North Sydney (Table 6), the absence of *B. schlosseri* at Sydney, and lower coverage of *B. violaceus* at North Sydney in 2011. In Bras d'Or Lake, water temperatures recorded at Eskasoni in 2010 were above 20°C from July to mid-September), with a higher peak (25°C) in late July. In 2011, water temperature fluctuated between 15 - 20°C from June to August, with a 23°C peak in mid-September. Coverage of *B. schlosseri* was lower at three of four stations monitored in this area in 2011 compared with 2010, and was low at Baddeck in both years.

The role of salinity in determining year-to-year variations in tunicate presence cannot be overlooked, however. Unfortunately, the three discrete readings gathered at monitoring stations annually as part of the current protocol are insufficient to allow meaningful analysis of the variability in coastal salinity. Stations located close to river outflows (Shelburne), or in Bras d'Or Lake, where salinity may drop below 15 psu (Appendix 2), may experience fluctuations in the presence and abundance of tunicate species. Epelbaum et al. (2009) found that *B. violaceus* tolerated salinities in the 20-38 psu range, which may explain its lack of establishment in the warm, brackish waters of Bras d'Or Lake to date.

The absence, or non-detection, of a species in subsequent years following its initial detection can signal that: (1) it has not survived through the winter in the new environment, or (2) that its density is aggregated or so low that it is not detected by the monitoring protocol used. Examples of the latter include; (1) the absence of *Ciona intestinalis* at St. Peter's in 2010, yet present from 2007-2009 and again in 2011 (2) *B. schlosseri*, present in low numbers throughout Halifax Harbour (Vercaemer and Sephton 2014), but absent from monitoring plates at BIO in 2006, 2007 and 2010, and (3) the presence of *B. violaceus* in Shelburne in 2007 and 2011 only (Table 6; Sephton

et al. 2011). The monitoring protocol employed in areas where tunicates have not been observed, or where infestations are very low, should be adjusted to include: (1) additional "search time" to examine fixed structures, (2) the deployment of additional monitoring collectors, or (3) the use of modified collectors with shading saucers and additional fouling surfaces (2006 collector: Sephton et al. 2011). There have been instances, however, such as the occurrence *D. listerianum* at Havre Aubert, QC in the summer of 2008, where tunicates have not survived their initial introduction (Simard et al. 2013). However, negative reports in two consecutive years are required before a water body is considered "tunicate free" and shellfish transfers can resume in PEI (Locke et al. 2009).

4.3 DISTRIBUTION OF NON-TUNICATE BIOFOULERS

4.3.1 *Membranipora membranacea*

Membranipora membranacea was present at 23 of 33 and at 24 of 31 monitoring sites in 2010 and 2011, respectively. These sites were located throughout the province, and were in areas well beyond what is thought to be the initial point of introduction on the south shore (Scheibling et al. 1999). Temperatures in coastal shallow waters are within the tolerance range of this species (Burridge 2012), and population outbreaks have been associated with warmer summer and autumn water temperatures (Saunders and Metaxas 2008) and acceleration of colony growth on kelp beds (Scheibling and Gagnon 2009). This species alters benthic community structure through encrustation on kelp blades, resulting in mass defoliation and replacement of native kelp by less desirable species such as the invasive alga *Codium fragile fragile* (Schiebling and Gagnon 2006; Schmidt and Scheibling 2007).

4.3.2 *Caprella mutica*

Caprella mutica was observed at 9 of 33 and 12 of 31 monitoring stations in 2010 and 2011, respectively, located throughout the province. The species is present on several shellfish aquaculture sites, and on artificial structures at many biofouling monitoring locations throughout Nova Scotia (Sephton et al. 2014). With a temperature tolerance between -1.8 to 25°C, and a salinity tolerance between 11 and 35, (Turcotte and Saint-Marie, 2009), this highly productive species is likely to survive and spread throughout Atlantic Canada. Since it is found only on artificial structures, its impacts on native communities and habitats are unknown.

5.0 CONCLUDING REMARKS

Given the number of established NIS in Nova Scotia, and the potential for introduction of new species from other regions through several vectors, it is imperative that DFO's AIS monitoring program continue in Atlantic Canada. Several areas for improvement, or continuity of effort, have been identified during the course of monitoring in 2011, or have arisen from more recent research and monitoring efforts. These include:

1. Increased monitoring in areas identified as "high risk" for species introduction

   The results of biofouling monitoring in coastal Nova Scotia in 2011 confirmed the presence of established populations of *C. intestinalis*, *B. schlosseri* and *B. violaceus* on the southwestern and south shores, in the Halifax area, in Chedabucto Bay and Isle Madame, and in coastal Cape Breton. The subsequent discovery of one tunicate species new to Nova Scotia; *S. clava*, and two species new to eastern Canada; *D. listerianum* and *A. aspersa* late in 2012 (Vercaemer et al. 2013; Moore et al. 2014), occurred in three separate areas (south shore including Lunenburg, Halifax and Chedabucto Bay) identified as at high risk of new species invasions through shipping vectors (DiBacco et al. 2012; Lacoursiere-Roussel et al. 2012a). The arrival and detection of more tunicates species on DFO's watch list (Locke 2009) may occur in these, and other ports, such as Yarmouth, Shelburne and Sydney, so monitoring efforts should be continued and enhanced in these locations, either by monitoring at more stations, or deploying additional collectors at individual stations. The north shore of Nova Scotia, monitored by DFO Gulf Region, remains at risk for invasion by *S. clava* and *C. intestinalis* from PEI and Chedabucto Bay, so communication and co-ordination between Gulf and Maritimes Regions should continue to ensure that key stations are monitored, given the threats of AIS to shellfish aquaculture in this area.

2. Increased efforts to detect *Didemnum vexillum* in coastal areas

   Rapid Assessments conducted in southwest New Brunswick (Martin et al. 2010) and southwest Nova Scotia (Sephton, pers. comm.), and annual biofouling monitoring efforts (Martin et al. 2011, Sephton et al. 2011) have not detected the presence of *D. vexillum* in coastal Nova Scotia or in the Bay of Fundy. However, it was confirmed off Parrsboro, NS, in the Minas Basin of the upper Bay of Fundy in the fall of 2012 (Moore et al. 2014) based on a report and sample collection by a local citizen. Subsequent coastal surveys in the Bay of Fundy and on Georges, Browns and German Banks indicate that the species is concentrated in the upper Bay of Fundy, with one additional location off Digby, and one additional location off

Yarmouth (B. Vercaemer, pers comm.). Monitoring efforts including survey and rapid assessment work, outreach to encourage the reporting of new infestations by local stakeholders and additional on-site searches complementing the deployment of settlement plates should be continued in these areas.

3. Focused monitoring of the entrances to the Bras d'Or Lake

To date, *B. schlosseri* is the only tunicate present in this region, although both *C. intestinalis* and *B. violaceus* have probably been introduced, based on the volume of recreational traffic into this water body. While conditions in the inner Lake may not be amenable to survival and growth of these species, it is important that monitoring at the entrances of the Lake (St. Peter's and Little Bras d'Or) continue as a means of early detection of the arrival of these species. The largest, tunicate-free mussel farm in Nova Scotia is located at St. Ann's Bay, so it is vital to prevent the arrival of *C. intestinalis* on these leases.

4. Ongoing co-ordination of research and monitoring efforts, and collaboration and outreach with stakeholders.

The detection of the new invaders in 2012 would not have been possible without co-ordination and information sharing between DFO research and monitoring staff. Given that the current monitoring protocol relies on a balance between the deployment of a small number of monitoring collectors (six) at each of 50-70 monitoring stations annually, it is important that information from ongoing research on biofouling dynamics and species presence that deploy additional collectors at some of these stations is included in annual monitoring results. Monitoring partnerships with local stakeholder groups and private citizens continue to facilitate monitoring efforts at additional stations. Ongoing outreach in the form of media events, posting of AIS posters at marinas and harbours and provision of identification materials, and presentations at Fisheries and Marina meetings and Boat Shows will enhance reporting of established and new AIS. Combined, these initiatives will result in a more comprehensive picture of annual AIS presence in Nova Scotia.

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Appendix 1: Details of monitoring and tunicate coverage on individual collectors at each station in 2011 Stations are grouped by geographical Region or Bay. Species coverage are given for top, middle and bottom plates (x,y,z), where 0 = no tunicate coverage, 1 = <25% coverage, 2 = 26-50% coverage, 3 = 51-75% coverage, and 4 = 76-100% coverage. Minilog thermistors (blue text) were deployed at several stations. (C.i. = *Ciona intestinalis,* B.s. = *Botryllus schlosseri*, B.v. = *Botrylloides violaceus*, P= Present (non-monitoring plate report) and A = Absent (non-monitoring plate report) ** = tunicates present at station, but not on monitoring collector) and nf = no fouling.

Region	Stn No.	Location	Monitored By	Deployment Dates	Deployment Period (days)	C.i. cover	B.s. cover	B.v. cover
Southwest shore	1	Digby	CARP	First (7 June – 12 August)	66	0,0,0	0,0,0	0,0,0
				First (7 June – 12 August)	66	0,0,0	0,0,0	0,0,0
		Minilog		Second (12 August - 13 October)	62	1,0,0	1,0,1	1,1,1
				Second (12 August - 13 October)	62	1,1,0	0,1,0	0,1,0
				Full (7 June – 13 October)	128	0,0,0	1,1,1	1,0,0
				Full (7 June – 13 October)	128	1,0,0	0,0,0	1,0,1
	2	Meteghan	DFO	First (3 June – 10 August)	68	1,0,0	1,1,1	1,1,1
				First (3 June – 10 August)	68	1,1,1	1,2,1	1,1,1
				Second (10 August – 19 October)	70	0,0,0	1,1,1	3,2,2
				Second (10 August – 19 October)	70	lost	lost	lost
				Full (3 June – 19 October)	138	4,4,4	0,0,0	0,0,0
				Full (3 June – 19 October)	138	4,4,4	0,0,0	0,0,0
	4	Yarmouth Bar	DFO	First (3 June – 11 August)	69	0,0,0	0,0,0	0,0,0
				First (3 June – 11 August)	69	0,1,1	1,1,1	0,0,0
				Second (11 August – 19 October)	69	0,0,0	0,0,0	0,0,0
				Second (11 August – 19 October)	69	lost	lost	lost
				Full (3 June – 19 October)	138	0,0,0	0,1,0	0,1,1
				Full (3 June – 19 October)	138	0.0.0	1,0,1	2,1,2
	108	Eel Lake	DFO	Full (15 June – 15 December)	183	0,0,0	0,0,0	0,0,0
				Full (15 June – 15 December)	183	0,0,0	0,0,0	0,0,0
		Minilog		Full (15 June – 15 December)	183	0,0,0	0,0,0	0,0,0
				Full (15 June – 15 December)	183	0,0,0	0,0,0	0,0,0

Appendix 1. continued.

Region	Stn No.	Location	Monitored By	Deployment Dates	Deployment Period (days)	C.i. cover	B.s. cover	B.v. cover
Southwest shore	7	Camp Cove	DFO	First (2 June – 10 August)	69	4,4,4	0,0,0	0,0,1
				First (2 June – 10 August)	69	4,4,3	1,1,1	1,0,1
				Second (10 Aug – 19 October)	69	4,3,1	0,0,1	0,1,1
				Second (10 Aug – 19 October)	69	3,4,3	1,0,0	0,0,0
				Full (2 June – 19 October)	138	3,3,4	0,0,0	0,0,0
				Full (2 June – 19 October)	138	4,4,4	0,0,0	0,0,0
	8	Clark's Harbour	DFO	First (19 May – 4 August)	77	1,1,1	1,1,1	0,0,0
				First (19 May – 4 August)	77	1,0,1	1,1,1	0,0,0
				Second (4 August – 18 October)	70	1,1,1	2,1,1	0,1,0
				Second (4 August – 18 October)	70	1,1,1	3,2,1	0,0,1
				Full (19 May – 18 October)	177	1,2,1	1,2,1	1,0,0
				Full (19 May – 18 October)	177	2,4,1	1,0,1	0,0,0
South shore	13	Lockeport Minilog	DFO	First (2 June – 10 August)	69	1,0,0	0,0,0	1,1,3
				First (2 June – 10 August)	69	lost	lost	lost
				Second (10 August – 18 October)	69	0,0,0	0,0,0	4,4,4
				Second (10 August – 18 October)	69	0,0,0	0,0,0	1,1,2
				Full (2 June – 18 October)	138	3,4,4	0,0,0	1,0,0
				Full (2 June – 18 October)	138	4,4,1	0,1,1	0,1,0
	12	Shelburne	DFO	First (2 June – 10 August)	69	4,3,3	0,0,1	0,0,0
				First (2 June – 10 August)	69	3,4,4	0,0,1	0,0,0
				Second (10 August – 19 October)	70	4,4,1	0,0,1	0,0,0
				Second (10 August – 19 October)	70	4,4,4	0,0,0	0,0,0
				Full (2 June – 19 October)	139	4,4,4	0,0,0	***
				Full (2 June – 19 October)	139	4,4,4	0,0,0	0,0,0

Appendix 1, continued

Region	Stn No.	Location	Monitored By	Deployment Dates	Deployment Period (days)	C.i. cover	B.s. cover	B.v. cover
South shore	82	Port Mouton	DFO	First (2 June – 10 August)	69	0,0,0	0,0,0	0,0,0
				First (2 June – 10 August)	69	0,0,0	1,0,0	0,0,0
				Second (10 August – 18 October)	69	0,0,0	0,0,0	0,0,0
				Second (10 August – 18 October)	69	0,0,0	0,0,0	0,0,0
				Full (2 June – 18 October)	138	0,0,0	0,1,0	0,0,0
				Full (2 June – 18 October)	138	0,0,0	4,1,1	0,0,0
	18	Lunenburg	DFO	First (1 June – 9 August)	69	0,0,0	4,4,2	1,1,1
				First (1 June – 9 August)	69	4,4,4	0,0,0	0,0,0
				Second (9 August – 17 October)	69	0,0,0	1,1,1	1,1,1
				Second (9 August – 17 October)	69	lost	lost	lost
				Full (1 June – 17 October)	138	4,4,4	0,0,0	1,1,1
				Full (1 June – 17 October)	138	lost	lost	lost
	19	Indian Point (1) Minilog	DFO	First (31 May – 8 August)	69	3,2,2	0,1,0	***
				First (31 May – 8 August)	69	4,1,2	1,0,0	0,0,0
				Second (8 August – 25 October)	78	3,3,2	1,1,2	0,0,0
				Second (8 August – 25 October)	78	2,2,3	0,0,0	0,0,0
	19	Indian Point (2) Minilog	DFO	First (14 June – 8 Aug)	55	0,0,0	0,0,0	0,0,0
				First (14 June – 8 Aug)	55	0,0,0	0,0,0	0,0,0
				Second (8 August – 25 October)	78	0,0,0	0,0,0	0,0,0
				Second (8 August – 25 October)	78	0,0,0	0,0,0	0,0,0
	19	Indian Point (3) Minilog	DFO	First (31 May – 8 August)	69	1,1,1	0,0,0	0,0,0
				First (31 May – 8 August)	69	0,0,0	0,0,0	0,0,0
				Second (8 August – 25 October)	78	1,4,3	0,0,0	0,0,0
				Second (8 August – 25 October)	78	0,0,0	0,0,0	0,0,0

Appendix 1, continued

Region	Stn No.	Location	Monitored By	Deployment Dates	Deployment Period (days)	C.i. cover	B.s. cover	B.v. cover
South shore	21	Chester	DFO	First (1 June – 23 August)	83	0,0,0	2,2,2	1,0,1
				First (1 June – 23 August)	83	0,0,0	4,4,4	1,0,0
				Second (23 August - 17 October)	55	1,0,0	1,1,1	0,0,0
				Second (23 August - 17 October)	55	0,1,0	2,1,1	0,0,1
				Full (1 June – 17 October)	138	0,0,0	0,1,0	1,1,1
				Full (1 June – 17 October)	138	1,1,1	1,0,0	1,1,1
HRM	83	Sambro	DFO	Full (11 July – 1 November)	113	lost	lost	lost
				Full (11 July – 1 November)	113	lost	lost	lost
				Full (11 July – 1 November)	113	4,4,4	0,0,0	0,1,0
				Full (11 July – 1 November)	113	4,4,4	0,0,0	0,1,1
	24	Halifax; BIO Jetty	DFO	First (17 June – 29 July)	42	1,1,1	0,1,0	0,0,0
				First (17 June – 29 July	42	1,1,1	0,0,0	0,0,0
				Second (29 July – 15 October)	78	4,3,4	1,0,1	0,0,0
				Second (29 July – 15 October)	78	0,0,1	0,0,0	0,0,0
				Full (17 June – 15 October)	120	0,0,0	0,0,0	0,0,0
				Full (17 June – 15 October)	120	0,3,3	0,0,0	0,0,0
	401	Halifax; Armdale Yacht Club	DFO	Report (October 2011)	NA	P	P	A
Eastern shore	25	Ship Harbour Minilog	DFO	Full (4 July – 9 December)	158	0,0,0	0,0,0	0,0,0
				Full (4 July – 9 December)	158	0,0,0	0,0,0	0,0,0
				Full (4 July – 9 December)	158	0,0,0	0,0,0	0,0,0
				Full (4 July – 9 December)	158	0,0,0	0,0,0	0,0,0
	104	Country Harbour	NSDFA	Report (November 2011)	NA	P		
	36	Whitehead	NSDFA	Report (November 2011)	NA	P		

Appendix 1, continued

Region	Stn No.	Location	Monitored By	Deployment Dates	Deployment Period (days)	C.i. cover	B.s. cover	B.v. cover
Chedabucto Bay	39	Cape Canso	DFO	First (8 June – 2 August)	55	1,0,0	0,0,0	0,0,0
				First (8 June – 2 August)	55	1,1,0	0,0,0	0,0,0
				Second (2 August – 11 October)	70	0,0,0	0,0,0	0,0,0
				Second (2 August – 11 October)	70	1,1,1	1,1,0	1,0,0
				Full (8 June – 11 October)	125	2,1,1	1,0,1	0,0,0
				Full (8 June – 11 October)	125	lost	lost	lost
	41	Venus Cove	DFO	First (6 June – 2 August)	57	1,1,1	0,0,0	0,0,0
				First (6 June – 2 August)	57	1,1,1	0,0,0	0,0,0
				Second (2 August – 11 October)	70	1,1,1	0,0,0	0,0,0
				Second (2 August – 11 October)	70	0,1,0	0,0,0	0,0,0
				Full (6 June – 11 October)	127	1,4,4	0,0,0	0,0,0
				Full (6 June – 11 October)	127	0,1,1	1,0,0	0,0,0
	44	Petit-de-Grat	DFO	First (7 June – 3 August)	57	1,1,1	0,0,0	0,0,0
				First (7 June – 3 August)	57	1,1,1	0,0,0	0,0,0
				Second (3 August – 12 October)	70	2,2,3	1,1,1	1,1,1
				Second (3 August – 12 October)	70	4,3,3	0,0,0	1,1,1
				Full (7 June – 12 October)	127	4,4,4	0,0,0	1,1,2
				Full (7 June – 12 October)	127	4,4,4	0,0,0	1,1,1
	45	D'Escousse	DFO	First (7 June – 3 August)	57	lost	lost	lost
				First (7 June – 3 August)	57	lost	lost	lost
				Second (3 August – 12 October)	70	0,0,1	0,0,1	0,0,2
				Second (3 August – 12 October)	70	1,1,0	0,1,1	1,1,1
				Full (7 June – 12 October)	127	0,0,0	0,0,0	1,0,0
				Full (7 June – 12 October)	127	lost	lost	lost
	80	Robin's Cove	NSDFA	Report (November 2011)	NA	P		

Appendix 1, continued.

Region	Stn No.	Location	Monitored By	Deployment Dates	Deployment Period (days)	C.i. cover	B.s. cover	B.v. cover
Cape Breton	46	Little Harbour	DFO	Report (October 2011)	NA	P	P	P
	58	Louisbourg	DFO	First (7 June – 3 August)	57	1,1,0	0,0,0	0,0,0
				First (7 June – 3 August)	57	1,1,1	0,0,0	0,0,0
				Second (3 August – 12 October)	70	4,4,2	1,1,2	0,0,0
				Second (3 August – 12 October)	70	0,0,1	1,3,1	0,0,0
				Full (7 June – 12 October)	127	4,4,4	1,0,1	0,0,0
				Full (7 June – 12 October)	127	2,1,1	3,4,2	0,0,0
	62	Sydney	DFO	First (7 June –3 August)	57	1,1,0	0,0,0	0,0,0
				First (7 June –3 August)	57	1,1,1	0,0,0	0,0,0
				Second (3 August – 13 October)	71	0,0,0	0,0,0	0,0,0
				Second (3 August – 13 October)	71	1,1,0	0,0,0	0,0,0
				Full (7 June – 13 October)	128	0,0,0	0,0,0	0,0,0
				Full (7 June – 13 October)	128	lost	lost	lost
	63	North Sydney	DFO	First (8 June – 4 August)	57	1,0,1	0,0,0	0,1,0
				First (8 June – 4 August)	57	1,1,1	0,0,0	0,0,0
				Second (4 August – 13 October)	70	0,0,0	1,1,2	4,4,3
				Second (4 August – 13 October)	70	lost	lost	lost
				Full (8 June – 13 October)	127	0,0,0	0,1,0	1,4,4
				Full (8 June – 13 October)	127	0,0,0	1,1,1	1,2,3

Appendix 1, continued.

Region	Stn No.	Location	Monitored By	Deployment Dates	Deployment Period (days)	C.i. cover	B.s. cover	B.v. cover
Cape Breton	74	Little River	DFO	First (8 June – 4 August)	57	0,0,0	1,0,0	0,0,0
				First (8 June – 4 August)	57	0,0,0	1,0,0	0,0,0
				Second (4 August – 13 October)	70	0,0,0	1,2,1	0,0,0
				Second (4 August – 13 October)	70	0,0,0	3,3,1	0,0,0
				Full (8 June – 13 October)	127	0,0,0	4,1,1	0,0,0
				Full (8 June – 13 October)	127	0,0,0	2,1,1	0,0,0
	75	St. Ann's Bay	DFO	Full (15 June – 19 October)	126	0,0,0	0,0,0	0,0,0
				Full (15 June – 19 October)	126	0,0,0	0,0,0	0,0,0
				Full (15 June – 19 October)	126	0,0,0	0,0,0	0,0,0
				Full (15 June – 19 October)	126	0,0,0	0,0,0	0,0,0
	69	Dingwall	DFO	Full (8 June – 13 October)	127	0,0,0	2,1,1	2,3,2
				Full (8 June – 13 October)	127	0,0,0	0,0,0	0,0,0**
	94	Aspy Bay, North Harbour Minilog	DFO	Anecdotal (November 2011)	NA	A	A	A

Appendix 1, continued

Region	Stn No.	Location	Monitored By	Deployment Dates	Deployment Period (days)	C.i. cover	B.s. cover	B.v. cover
Bras d'Or Lake	47	St. Peter's	DFO	First (7 June – 3 August)	57	0,0,0	0,0,0	0,0,0
				First (7 June – 3 August)	57	0,0,0	0,0,0	0,0,0
				Second (3 August – 12 October)	70	1,0,0	2,2,4	0,0,0
				Second (3 August – 12 October)	70	0,1,0	4,3,3	0,0,0
				Full (7 June – 12 October)	127	0,1,0	4,4,2	0,0,0
				Full (7 June – 12 October)	127	0,0,0	2,1,4	0,0,0
	51	Whycocomagh	EFWC	First (6 June – 9 August)	64	0,0,0	0,0,0	0,0,0
				First (6 June – 9 August)	64	0,0,0	0,1,0	0,0,0
				Second (9 August– 3 November)	86	0,0,0	0,1,2	0,0,0
				Second (9 August – 3 November)	86	0,0,0	1,4,4	0,0,0
				Full (31 May – 3 November)	150	0,0,0	1,1,0	0,0,0
				Full (31 May – 3 November)	150	0,0,0	0,0,0	0,0,0
	52	Orangedale	EFWC	First (6 June – 9 August)	64	0,0,0	0,0,0	0,0,0
				First (6 June – 9 August)	64	0,0,0	0,0,0	0,0,0
				Second (9 August – 3 November)	86	0,0,0	0,0,0	0,0,0
				Second (9 August – 3 November)	86	0,0,0	0,0,0	0,0,0
				Full (31 May – 3 November)	150	0,0,0	0,0,0	0,0,0
				Full (31 May – 3 November)	150	0,0,0	0,0,0	0,0,0
	54	Eskasoni Minilog	EFWC	First (6 June – 9 August)	64	0,0,0	1,1,0	0,0,0
				First (6 June – 9 August)	64	lost	lost	lost
				Second (9 August – 3 November)	86	0,0,0	4,1,0	0,0,0
				Second (9 August – 3 November)	86	0,0,0	3,2,1	0,0,0
				Full (31 May – 3 November)	150	0,0,0	1,1,0	0,0,0
				Full (31 May – 3 November)	150	lost	lost	lost
	55	Baddeck	DFO	Second (4 August – 14 October)	128	0,0,0	1,0,2	0,0,0
				Second (4 August – 14 October)	128	0,0,0	1,1,1	0,0,0
	86	East Bay	DFO	Full (6 July – 9 November)	126	0,0,0	1,1,1	0,0,0
				Full (6 July – 9 November)	126	0,0,0	1,1,1	0,0,0

Appendix 2: Environmental variables measured using YSI probes at monitoring stations in 2011. Substation numbers are given for Indian Point. ChlA = chlorophyll a, IPMF = Indian Point Marine Farms, BIO = Bedford Institute of Oceanography, N/A = no data.

Region	Stn. No.	Location	Sample Date	Probe Depth, m	YSI Type	Temp, °C	Salinity	Oxygen, %	Oxygen, mg L^{-1}	Conductivity, mS cm^{-1}	ChlA, µg L^{-1}	pH
Southwestern Shore	1	Digby	07-Jun	1.00	Quanta	10.20	30.80	107.60	9.89	48.10	N/A	7.89
			12-Aug	1.00	Quanta	12.20	31.10	84.80	7.45	48.90	N/A	7.78
			13-Oct	1.00	Quanta	12.23	30.80	98.20	8.67	47.40	N/A	7.46
	2	Meteghan	03-Jun	1.32	6600	10.37	31.05	95.70	8.91	47.90	1.16	7.96
			10-Aug	1.00	6600	14.07	31.39	98.90	8.37	48.15	1.42	8.15
			19-Oct	0.89	6600	12.79	32.22	87.10	7.54	49.35	0.90	N/A
	4	Yarmouth Bar	03-Jun	0.93	6600	10.23	30.46	98.70	9.13	47.09	1.29	7.85
			10-Aug	1.00	6600	13.47	31.35	96.70	8.30	48.12	0.77	8.01
			19-Oct	0.86	6600	12.92	26.50	89.10	7.97	41.38	1.80	N/A
	7	Camp Cove	03-Jun	1.04	6600	14.51	29.41	103.30	8.78	45.40	2.77	8.26
			10-Aug	0.80	6600	16.14	30.84	97.90	7.99	47.33	0.64	8.31
			19-Oct	0.92	6600	14.05	30.43	89.70	7.65	46.82	3.80	N/A
	8	Clark's Harbour	02-Jun	0.91	6600	12.53	30.19	97.50	8.60	46.56	0.90	8.10
			10-Aug	1.00	6600	15.84	30.64	103.10	8.44	47.07	1.03	8.30
			18-Oct	0.75	6600	13.67	28.31	83.20	7.25	43.89	2.19	N/A
	13	Lockeport	02-Jun	1.34	6600	8.48	30.15	95.30	9.18	46.82	1.35	8.13
			10-Aug	1.00	6600	16.91	30.44	95.90	7.60	46.81	0.84	8.24
			18-Oct	0.78	6600	13.67	29.84	87.90	7.46	45.99	0.58	N/A

Appendix 2. continued

Region	Stn. No.	Location	Sample Date	Probe Depth, m	YSI Type	Temp, °C	Salinity	Oxygen, %	Oxygen, mg L^{-1}	Conductivity, mS cm^{-1}	ChlA, µg L^{-1}	pH
Southwestern shore	12	Shelburne	02-Jun	0.81	6600	14.10	24.85	92.50	8.16	38.99	3.73	7.82
			10-Aug	0.78	6600	16.38	30.05	99.40	8.12	46.23	1.09	8.28
			19-Oct	1.02	6600	14.50	26.40	89.50	7.76	41.17	0.52	N/A
	82	Port Mouton	02-Jun	1.33	6600	5.54	30.24	91.40	9.42	47.34	0.58	8.15
			10-Aug	1.00	6600	16.74	29.84	98.30	7.99	45.94	1.29	8.23
			18-Oct	0.56	6600	13.75	30.45	81.00	6.95	46.86	0.45	N/A
	18	Lunenburg	01-Jun	0.76	6600	12.44	29.51	117.20	10.40	45.62	0.19	8.16
			09-Aug	1.00	6600	17.10	29.82	97.90	7.89	46.01	1.74	7.40
			17-Oct	0.29	6600	13.82	27.67	94.40	8.23	42.99	2.45	N/A
	19 (1)	IPMF	31-May	5.00	6600	7.64	30.86	98.80	9.71	46.14	1.09	8.34
			08-Aug	4.90	6600	16.36	29.90	100.50	8.21	46.03	1.22	8.24
			25-Oct	5.00	6600	13.80	27.80	73.00	6.06	43.08	N/A	N/A
	19 (2)	IPMF	14-Jun	5.00	6600	12.60	26.80	88.30	7.79	41.86	N/A	N/A
			08-Aug	4.71	6600	16.61	29.85	100.70	8.19	45.96	1.67	8.35
			25-Oct	5.00	6600	13.80	27.70	63.60	5.20	43.09	N/A	N/A
	19 (3)	IPMF	31-May	5.00	6600	8.31	29.65	104.50	10.10	46.09	1.03	8.28
			08-Aug	4.55	6600	16.48	29.94	100.10	8.15	46.09	1.03	8.31
			25-Oct	5.00	6600	13.90	27.60	80.00	6.96	33.84	N/A	N/A
	21	Chester	01-Jun	1.07	6600	13.21	27.60	110.00	9.72	42.92	1.03	7.81
			23-Aug	0.78	6600	19.62	29.39	105.10	8.10	45.30	1.22	8.42
			17-Oct	1.04	6600	13.61	27.37	95.60	8.38	42.57	0.26	N/A

Appendix 2, continued.

Region	Stn. No.	Location	Sample Date	Probe Depth, m	YSI Type	Temp, °C	Salinity	Oxygen, %	Oxygen, mg L^{-1}	Conductivity, mS cm^{-1}	ChlA, µg L^{-1}	pH
HRM	83	Sambro	11-Jul	1.05	6600	14.17	30.15	110.00	9.37	46.42	1.03	8.24
			01-Nov	0.47	6600	9.82	29.51	95.60	8.98	45.80	0.84	N/A
	24	Halifax; BIO	17-Jun	0.84	6600	9.55	28.44	110.50	10.51	44.34	1.22	8.35
			29-Jul	1.00	6600	15.02	29.68	105.70	8.87	45.70	2.32	8.03
			15-Oct	0.92	6600	8.91	27.81	87.20	8.45	43.49	2.60	N/A
Eastern Shore	25	Ship Harbour	04-Jul	0.97	6600	18.29	16.92	102.40	9.84	23.93	3.41	8.32
			09-Dec	0.30	6600	7.10	20.26	92.80	8.71	21.53	2.64	N/A
Chedabucto Bay	39	Cape Canso	08-Jun	1.02	6600	7.46	30.17	97.50	9.66	47.02	0.77	7.79
			02-Aug	1.07	6600	15.12	30.02	99.30	8.31	46.24	0.90	8.12
			11-Oct	0.85	6600	14.22	28.98	99.80	8.56	44.81	1.10	N/A
	41	Venus Cove	06-Jun	1.07	6600	7.73	29.54	95.00	9.34	46.04	0.13	8.34
			02-Aug	1.00	6600	16.56	28.00	99.30	8.20	42.70	1.35	8.23
			11-Oct	0.94	6600	11.07	30.48	94.10	8.54	47.06	2.77	N/A
	44	Petit-de-Grat	07-Jun	1.49	6600	7.43	30.50	102.20	10.06	47.43	1.48	8.11
			03-Aug	1.40	6600	16.51	29.69	81.90	6.68	45.73	1.29	7.93
			12-Oct	0.99	6600	12.33	30.36	99.10	8.77	46.81	0.84	N/A
	45	D'Escousse	07-Jun	1.49	6600	9.67	29.89	97.90	9.19	46.34	0.84	8.23
			03-Aug	1.00	6600	16.90	29.11	95.50	7.75	44.90	1.61	8.16
			12-Oct	1.32	6600	11.42	29.81	101.70	9.20	46.10	1.03	N/A

Appendix 2, continued.

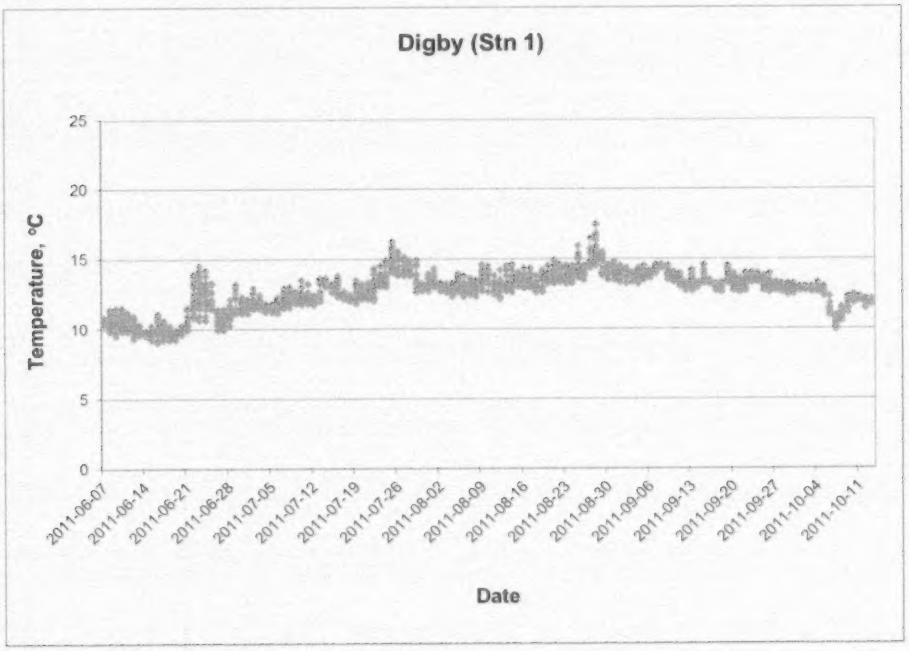
Region	Stn. No.	Location	Sample Date	Probe Depth, m	YSI Type	Temp, °C	Salinity	Oxygen, %	Oxygen, mg L^{-1}	Conductivity, mS cm^{-1}	Chl A, µg L^{-1}	pH
Bras d'Or Lake	47	St.Peter's	07-Jun	0.71	6600	11.48	19.95	100.90	9.70	32.01	1.48	8.35
			03-Aug	0.80	6600	18.81	17.45	99.50	8.36	28.31	3.29	8.35
			12-Oct	0.94	6600	13.98	20.90	102.10	9.25	33.32	1.74	N/A
	51	Whycocomagh	06-Jun	1.00	85	13.80	14.91	105.50	9.99	N/A	N/A	N/A
			09-Aug	1.00	85	18.00	16.51	84.90	7.28	N/A	N/A	N/A
			03-Nov	1.00	85	11.70	18.59	N/A	9.49	N/A	N/A	N/A
	52	Orangedale	06-Jun	1.00	85	15.10	14.70	101.40	9.27	N/A	N/A	N/A
			09-Aug	1.00	85	16.40	N/A	84.20	8.04	N/A	N/A	N/A
			03-Nov	1.00	85	7.60	12.58	N/A	11.37	N/A	N/A	N/A
	54	Eskasoni	06-Jun	1.00	85	12.10	18.74	95.30	9.07	N/A	N/A	N/A
			09-Aug	1.00	85	N/A	N/A	N/A	N/A	N/A	N/A	N/A
			03-Nov	1.00	85	10.70	18.23	93.00	9.26	N/A	N/A	N/A
	55	Baddeck	04-Aug	1.00	6600	17.83	21.47	99.00	8.25	34.20	1.03	8.28
			14-Oct	0.88	6600	14.22	22.41	98.70	8.81	35.51	1.80	7.88

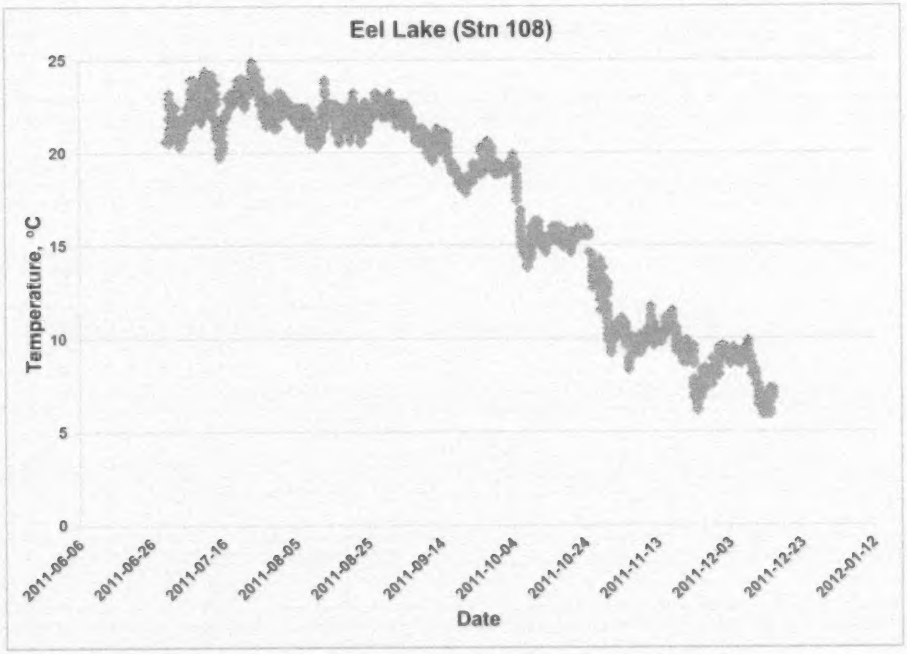
Appendix 2, continued.

Region	Stn. No.	Location	Sample Date	Probe Depth, m	YSI Probe Type	Temp, °C	Salinity	Oxygen, %	Oxygen, mg L^{-1}	Conductivity, mS cm^{-1}	ChlA, µg L^{-1}	pH
Cape Breton	58	Louisbourg	07-Jun	1.26	6600	7.07	29.70	93.90	9.37	46.35	0.06	8.19
			03-Aug	1.06	6600	15.51	28.33	87.00	7.33	43.92	2.64	8.15
			13-Oct	0.97	6600	13.23	29.71	102.30	8.92	45.86	1.16	N/A
	62	Sydney	07-Jun	0.90	6600	9.90	26.37	108.70	10.38	41.35	5.73	8.31
			03-Aug	0.99	6600	15.66	28.64	92.50	7.72	44.30	3.28	8.44
			13-Oct	0.93	6600	13.01	22.51	91.00	8.33	35.67	2.58	N/A
	63	North Sydney	07-Jun	1.10	6600	8.57	29.27	90.70	8.77	45.58	0.84	7.92
			03-Aug	1.00	6600	16.19	28.43	92.40	7.64	43.96	1.93	8.06
			13-Oct	0.95	6600	12.56	27.75	91.10	8.15	43.15	1.22	N/A
	74	Little River	08-Jun	1.02	6600	7.68	28.92	75.50	7.39	45.17	0.19	8.10
			04-Aug	1.00	6600	15.84	27.96	41.00	3.44	43.31	1.22	8.00
			13-Oct	0.58	6600	13.10	28.70	31.10	2.73	44.46	0.32	N/A
	69	Dingwall	08-Jun	N/A	6600	N/A	N/A	N/A	N/A	N/A	N/A	N/A
			13-Oct	0.93	6600	11.82	27.72	99.30	9.03	43.14	8.05	N/A

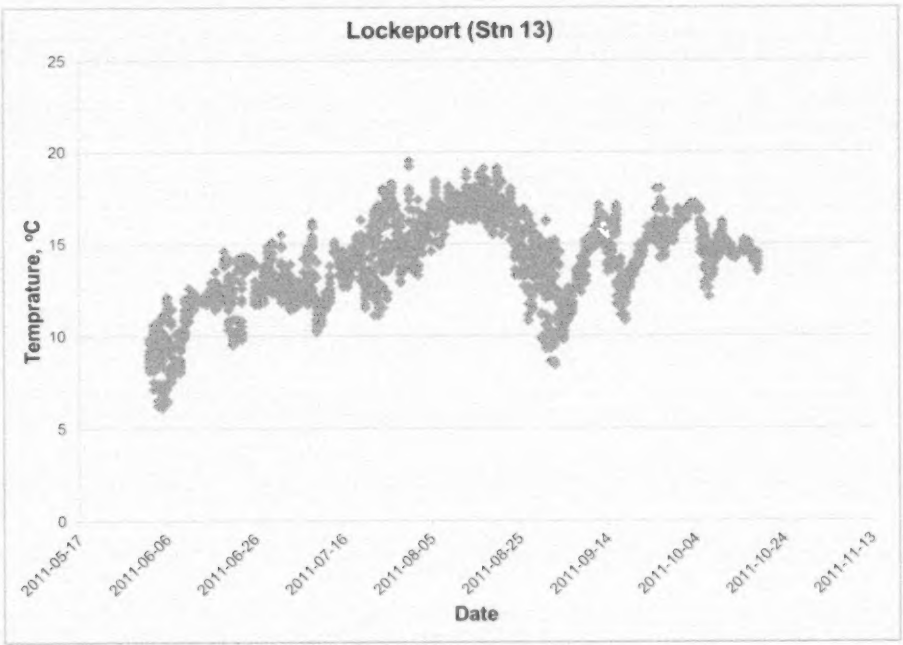
Appendix 3: Minilog temperature plots from monitoring stations, 2011.

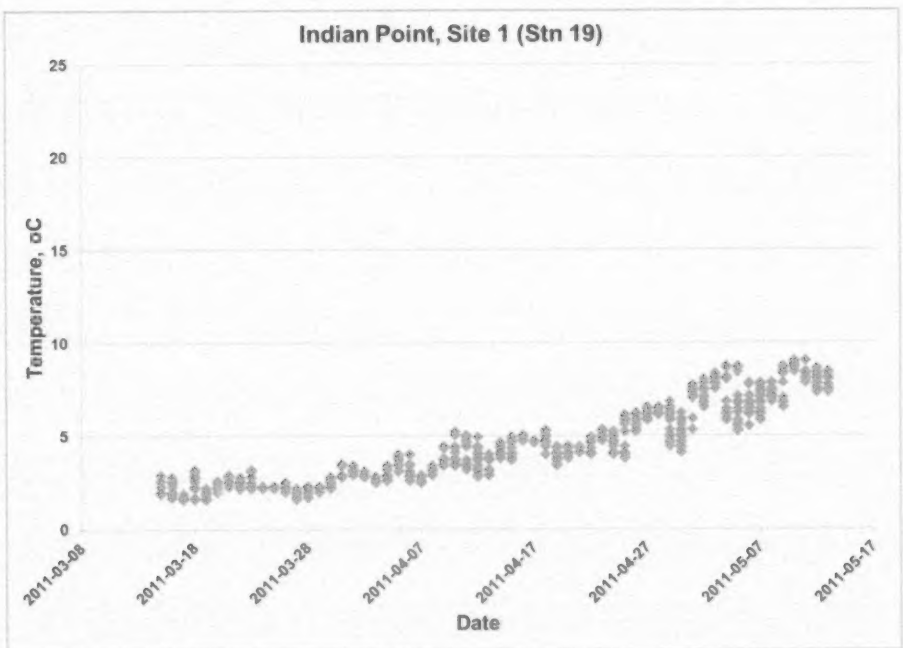
Southwestern shore (Digby to Clark's Harbour)



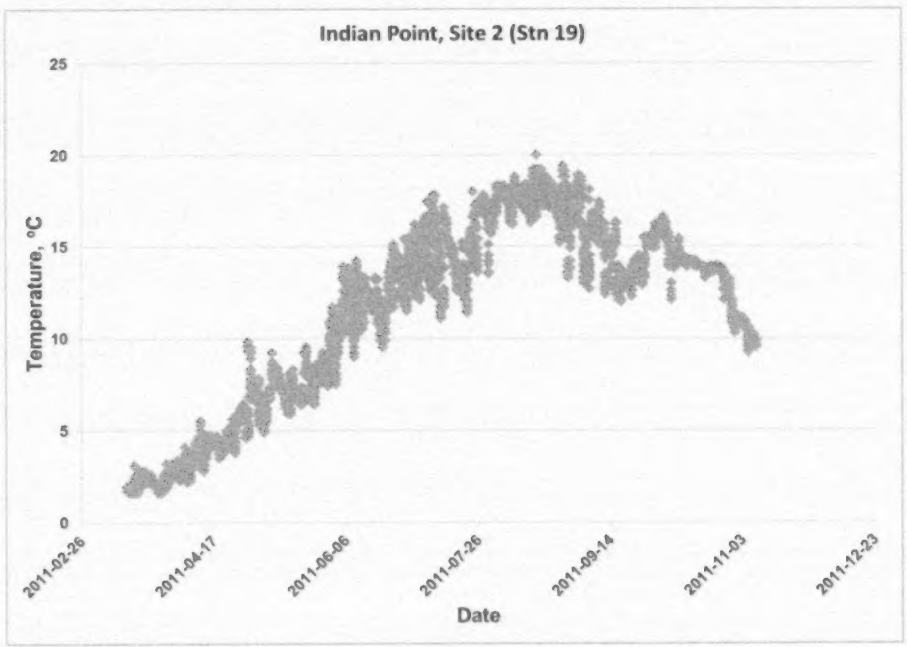


South shore (Lockeport to Chester)

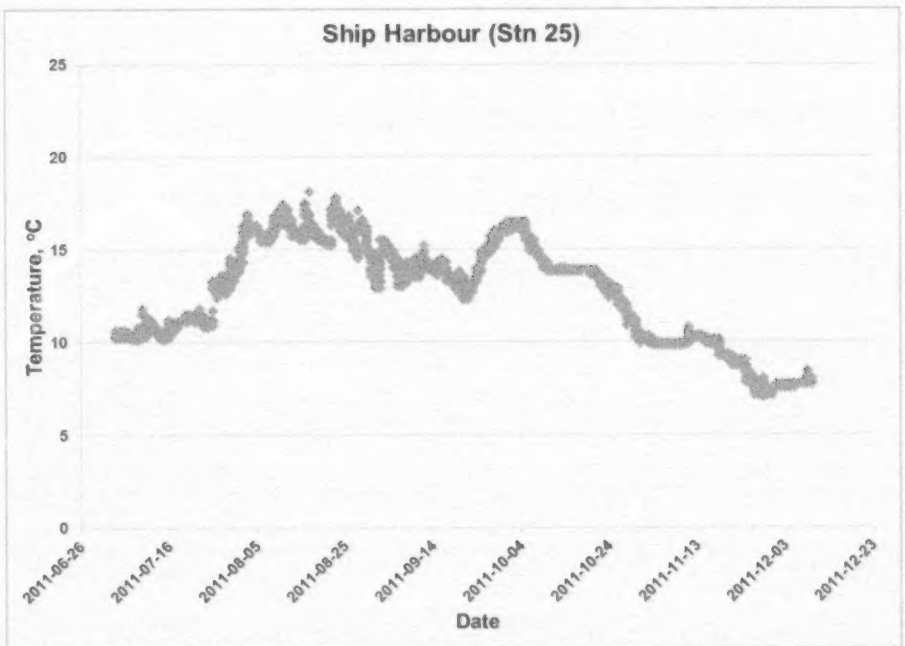




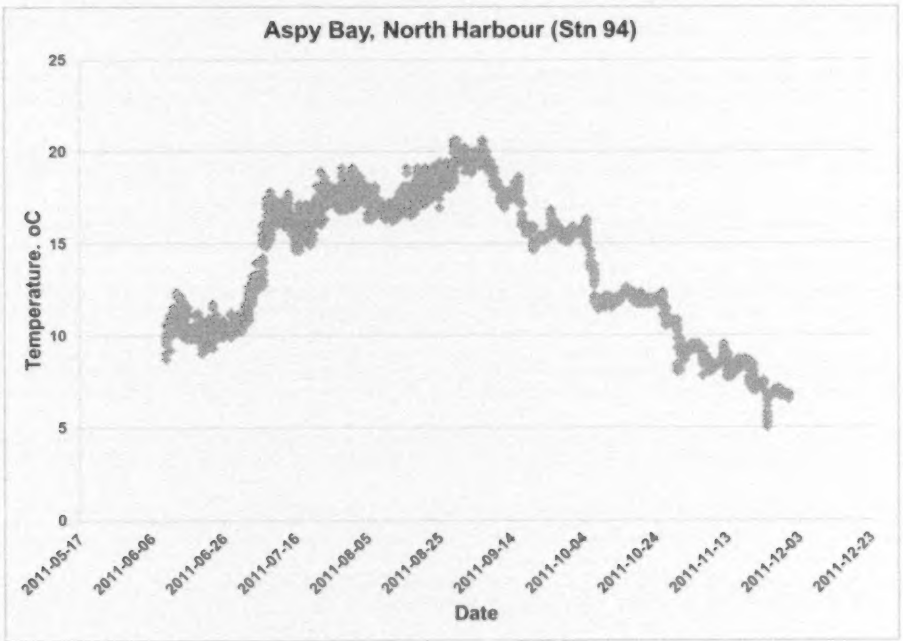
South shore (Lockeport to Chester)



Eastern Shore



Cape Breton



Bras d'Or Lake